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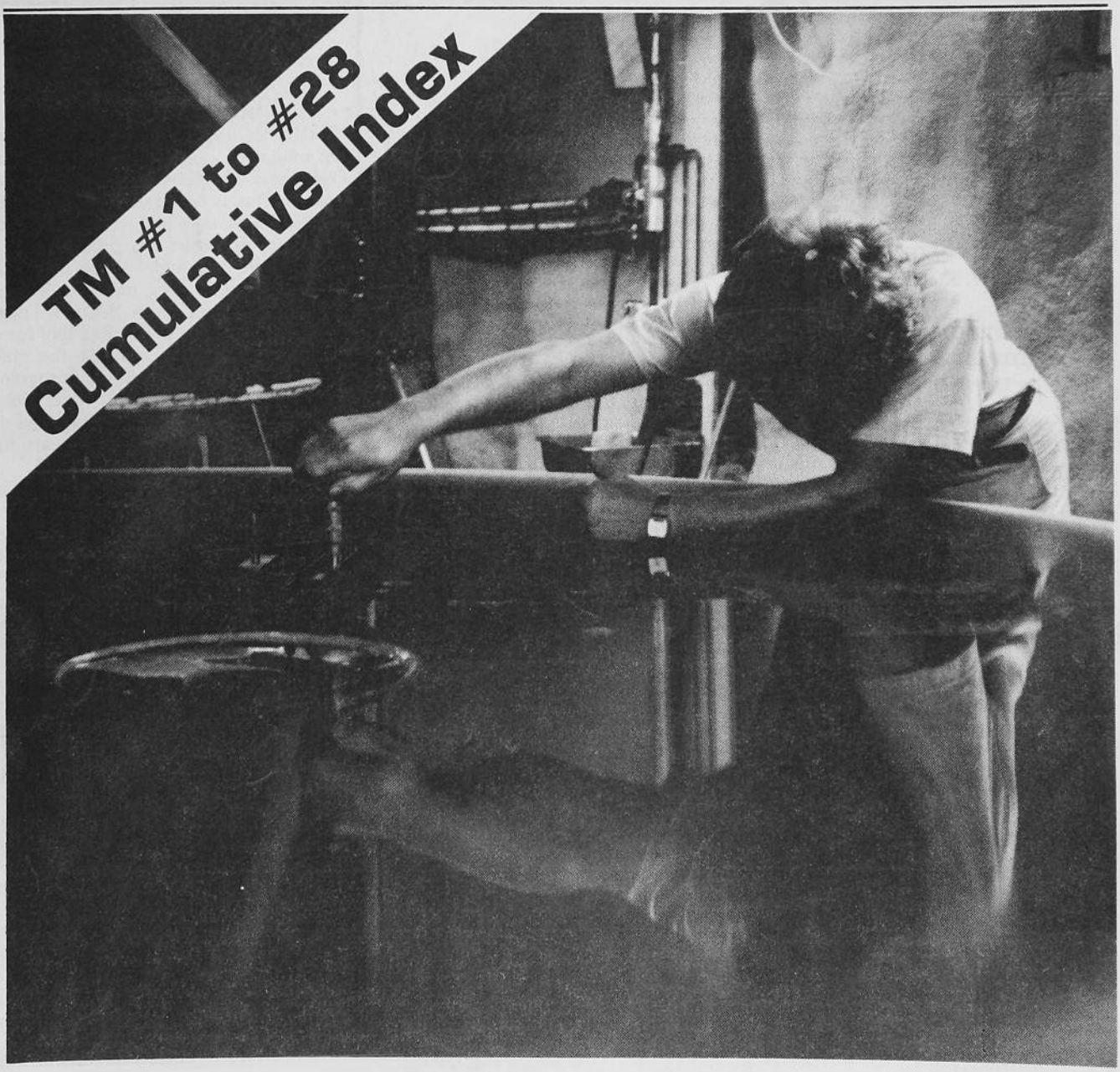

Telescope Making

The magazine *for, by,* and *about* telescope makers!

Editor: Richard Berry
Associate Editor: Robert E. Cox
Managing Editor: Steven Cole

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Cover: Tapio Korhonen of Tuorla Observatory checks the radius of the 2.5-meter primary for the Nordic Optical Telescope. Photo by Jukka Piironen.

Editorial

This issue of *Telescope Making* may look a lot like any other, but careful examination will reveal a number of odd new typefaces lurking in these pages. That is because, with this issue, *Telescope Making* has gone electronic. Much of this issue was produced on a Macintosh Plus and Laserwriter with text imported from our old Vector Graphic 2600s or ASTRONOMY'S new Kaypro XTs. As a publishing tool for a miniscule magazine like *TM*, the Mac is hard to beat. We're using a program called Ready, Set, Go! 3.0, which does the job pretty efficiently, though I'm still pretty far down on the learning curve.

For the computerphiles reading this — don't worry — *TM* will still accept article submissions on PC and PC-clone diskettes. Now, however, we're also able to use the Mac's mini-floppies ("stiffies," really), and, as always, text in the incredibly hard-to-find Vector Graphic 16HS QD 100TPI quad-density diskette format.

I'd prefer unformatted Microsoft Word documents, but can make do with just about anything saved as plain ASCII text files with an ASCII character 13 marking the end of paragraph, no soft returns, and no embedded commands. (As least, I think that's what Word makes when you save in unformatted mode.) Please be sure to include hard copy with any article sent on a diskette.

This issue includes a massive sixteen-page cumulative index to all prior issues of *TM* courtesy of *TM* reader Richard Mikovsky, which he sent to us on a floppy. We typeset it after running the whole file through a little filter program

to remove the file's Venix-style formatting, and there it is. I wish it included author names, but it is too good to turn down in its present form. I find it very useful, and I'm sure that you will, too.

This issue also contains a number of very significant articles. Heinz Klee's article on the Pretoria eyepiece offers us the prospect of good imagery from short-focus Newtonians, providing some daring company will come forward to manufacture these eyepieces.

Dick Suiter's article and program on apodizing finally gives all of us the tools we need to optimize these screens and explore what they can and cannot do. If you'd like a copy of the program, send me two diskettes and I'll send back one with the program, as I did for his program for mirror smoothness. Dick is also willing to make copies of APODIZE for *TM* readers and was a little upset that I said, "He won't" in the *TM#28* editorial. He will.

Another significant article is David Shafer's brief piece on an improved catadioptric design. I find it hard to believe that Celestron, Bushnell, and Meade apparently aren't going after designs like this. I suspect that the thick lens and spherical secondary would be a lot cheaper to manufacture than a Schmidt corrector plate and hyperboloidal secondary, but that the selling price of the finished instrument could be every bit as high. In any event, something like this could go a long way toward reviving the Maksutov Club.

I saw Tom O'Brien's ball-in-socket scope at last year's ASTROFEST. For medium-size instruments, this mount offers a good alternative to the Dobsonian, and it's every bit as easy to use. Of course it's somewhat harder to make, but that wouldn't deter a telescope maker.

Finally, articles on observatories have been rolling in. Whether they are some kind of response to the exchange in the Letters department several years ago ("Leaking Domes", etc.) or a simple statistical fluctuation, I'm pleased to see this influx of good write-ups on practical stuctures. I recently moved to the country, and the sky over my house is quite dark — so this summer I'm going to build an observatory for my 20-incher out back.

—RLB

Of Eyepieces and Prices

The purpose of magazines like *TM* is to provide the amateur with information on topics related to telescope making and optical accessories. With this in mind I would like to discuss the design and cost of eyepieces.

Since June 1985, I've had the privilege of owning the eyepiece described in the story and have taken the opportunity to demonstrate it at meetings. To say that the Pretoria eyepiece has caused a riot at meetings where it has been demonstrated is putting it mildly: one amateur at ASTROFEST 1985 swore he wouldn't buy another eyepiece until the Pretoria eyepiece came on the market.

Over the years I have asked many optical design engineers why it has not been possible to design an eyepiece that would correct the field errors of a paraboloid. I was particularly interested in correcting for coma in fast Newtonian telescopes that are now so popular for deep-sky observing. As you know, these have such small come-free fields that observing is restricted. When I mentioned this to my optical designer friend Heinz Klee in Pretoria, South Africa, a few years ago, he surprised me by designing and making just such a lens.

The first thing you'll probably say is that the Pretoria eyepiece is too complicated and would cost too much to make. It's not true. If you examine the optical diagrams of eyepieces that are currently selling like hotcakes, you will see many current ultra-wide eyepieces that are as complicated as the Pretoria eyepiece — and they are obviously quite saleable in today's market. In short, the Pretoria eyepiece is not too complex to bring to market.

But, while this is true, isn't it a bit crazy to spend more for a set of eyepieces than for a telescope? I think so. So an approach that I've been advocating to various vendors is to redesign some of the current wide-field eyepieces to give smaller apparent fields. The resulting eyepieces would be superb and could sell for a very reasonable price. The Super Plossl eyepiece now offered by one vendor is, when one investigates design parameters of known eyepieces, that of the highly respected Erfle eyepiece. Originally designed for an apparent field of 60 degrees, this eyepiece is even better when optimized for a field of 50 degrees.

Among the many fine observers I have known and corresponded with over the past fifty or more years was the late Horace Dall. He took me down a peg after I built a simple relay lens he described in Gleanings back in the early '60s and wrote to tell him I was disappointed in the edge definition. He replied, "Of course, if you want to view anything, bring it into the center of the field!" He was right, but I still wish he could have viewed through the Pretoria eyepiece. I know I could have changed his mind!

The sad thing about today's wide-field eyepieces is that there is no way their design tolerances can be lowered or the number of elements reduced, and that, the vendors say, is what makes them costly. But not entirely. Recently one vendor told me in a phone conversation that he could sell his eyepieces at lower prices but was afraid people might not understand. They would think his were not as good as the higher-priced competition. So his prices will stay high.

But we desperately need a new approach to help our hobby expand and to encourage new people to become interested. One can no longer call telescope making a "poor man's hobby." Because of this many young folks are being denied the opportunity to start the fascinating hobby. Hopefully when they reach the age of employment and start to earn an adequate income, they still retain that spark of interest.

If you want lower cost, high quality eyepieces and are willing to accept apparent fields of 50 degrees or thereabouts, write to the firms that make eyepieces and let them know. Right now, I know the vendors do not believe there is a market for such items. It is up to you to change that attitude — or you will never get any relief.

—R.E.C.

Letters

Alt-Az Tracking Device

Dear Mr. Berry / I am writing in reply to Mr. Fred Bieler's letter (Ain't Much I'm Askin', *TM#26*). Though Mr. Bieler found R. Buchroeder's article on eyepieces in *TM#25* uninformative because of the terms and graphs used, I found the article extremely informative, and I am only a high school graduate. I suspect the difference is that I have spent twenty or so interesting years studying and learning about the theoretical side of optics while I was building telescopes as a hobby. I suppose that it is all well and nice to build the same general type of instrument many times over, but I'd rather experiment. I am much more enthusiastic about spending my money on building a prototype for a new design than about "merely" building another

➤ 30

THE PRETORIA EYEPIECE

A New Look at Residual Aberration Correction in Amateur Telescopes

H. W. Klee and M. W. McDowell
Optical Sciences Division, National Physical Research Laboratory,
CSIR, P.O. Box 395, Pretoria 0001, South Africa

Abstract

In recent years the use of fast paraboloids in simple mountings, the so-called Dobsonian telescopes, have become very popular amongst amateur astronomers. This popularity can partly be ascribed to the relatively inexpensive construction and of course to the wide fields these instruments are supposed to afford.

The large amount of coma introduced by the paraboloid makes these telescopes less useful than desired, as it is precisely this aberration that limits the useful field even when employed visually.

To overcome this problem a 28mm focal length eyepiece has been designed for use with a f/4 paraboloid, having an apparent field of view of some 50 degrees. This eyepiece compensates for the coma to a very high degree, as the residual coma is less than ¼-wave over most of the field. It is also unusually well corrected for all other aberrations.

The ideas leading up to this design and the design itself are described in some detail in the following.

Introduction

A visual telescope system comprises three basic components: the objective system, the eyepiece, and the human eye. For any optical device to perform optimally, it should be designed as a system as is done in high quality microscopes, for example, where certain uncorrectable aberrations of the objective lens are compensated for in the eyepiece lens, resulting in the desired overall performance.

It is strange that this approach, to our knowledge, has never been adopted in the design of amateur astronomical telescopes using a paraboloid primary mirror. The reason for this is possibly historical, as the amateur himself made the telescope mirror, typically of about f/8 relative aperture, and often also the eyepiece. In this case the latter was usually of the simple Huygens construction and, although not optimal, such a combination would give reasonable results and would show features on the Moon or planets that would not be visible to the naked eye.

With time the amateur came to realize this telescope's shortcomings. As his mirror was usually of excellent finish, the lack of image quality had to arise elsewhere, namely in the eyepiece. This led to a market flooded with military surplus eyepieces such as variants of the Plossl, Erfle, and others. These eyepieces of course were designed for use in military instruments that almost certainly did not have a parabolic primary and that were intended for applications far removed from astronomy. In the military instrument the maximum possible field of view is often required, even if the edge of field performance falls far short of that on-axis.

This approach still allows the user to detect movement over a wide field, while the central portion of the field of view is used for close inspection of the moving object. The astronomer, on the other hand, is not interested in movement, but is concerned with the detail contained in the field and thus trades field of view for definition.

In recent years the use of fast paraboloids in simple mountings, Dobsonian telescopes, have become very popular amongst amateurs. These telescopes typically have a relative aperture as low as f/4 and provide a wide field of view, albeit with all the inherent aberrations of a paraboloid. Since the suppliers of eyepieces fail to take the overall system design approach, most, if not all, of the available eyepieces merely exaggerate this inherent aberration, particularly the coma, instead of providing passive compensation.

The need for a proper system approach to the problem was reinforced following discussions and correspondence with Bob Cox of *Telescope Making*, and the NPRL responded by funding a project to investigate the design of a compensating eyepiece for use with fast paraboloids. Following a successful design study, discussed in more detail below, several prototypes of the design, engineered for use by the amateur, were constructed, and these are currently available for evaluation by both American and South African amateur astronomers.

Design Considerations

The first step in the design of any optical system is to draw up the first order specification, which would include such parameters as focal length, field of view, etc. Consideration must also be given at this stage to the possible influence of other mechanical or ergonometric constraints (e.g. a 90-degree fold). Other fundamental constraints must also be taken into account, such as the diffraction limit, as it would be useless to expect a resolution of 300 cycles/mm for example from a relative aperture of f/10.

Drawing up a sensible (and realistic) specification is considerably more involved than is generally realized, and is often beset with potential contradictions. Consider the case of the compensating eyepiece. It might be thought that as the aberrations of the primary paraboloid are well established, an eyepiece could be designed that would be suitable for every potential astronomical application. In fact this is not the case, and it is necessary to decide whether the application is for the detection of the faint set star possible or for the study of faint extended objects. It will be shown that the requirements for viewing "point objects" are contradictory to those for "extended objects".

The magnification M of a telescope is $M = EN/EX$, where

EN and *EX* are the entrance and exit pupil diameters of the telescope, respectively. From simple geometry it follows that the area of the entrance pupil is M^2 larger than that of the exit pupil and therefore collects M^2 more light than the eye of the observer, provided the exit pupil is matched to that of the observer's eye. However, the apparent angle of the object presented to the eye is increased by M, and the illuminated area on the retina is therefore also increased by M^2, so that the illumination per unit area remains constant. The gain in illumination resulting from the larger entrance aperture is therefore cancelled by the magnification.

If the exit pupil *EX* is larger than that of the eye pupil then the iris effectively stops down the telescope and the overall effect is identical to that described above. Reducing the exit pupil diameter below that of the eye pupil also reduces the apparent brightness to below that perceived with the naked eye. This effect will have been observed by most amateurs in viewing an extended object such as the Moon, where the apparent image brightness changes with the magnification.

This reduction of the perceived brightness or luminosity can be expressed as follows:

$$L_1 = L_0 \times R \qquad (1)$$

where L_0 is the luminosity of an extended object as perceived by the unaided eye, L_1 the reduced luminosity due to a smaller exit pupil diameter, and R the reduction factor, which can be computed from the following expression.

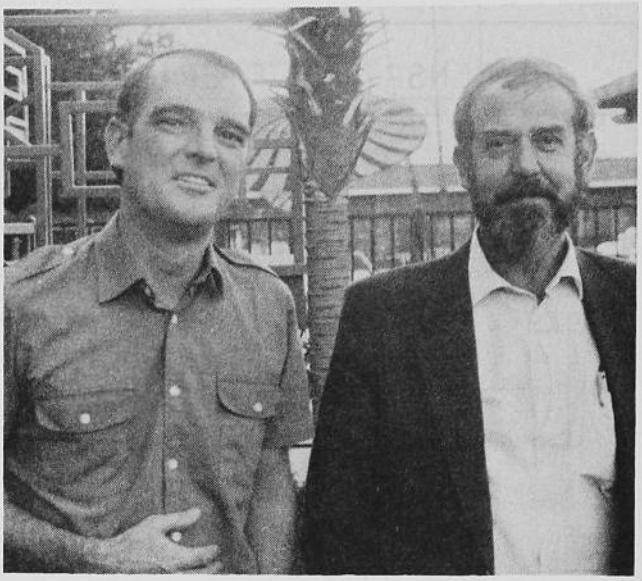
$$R = \left(\frac{EX}{OP}\right)^2; \qquad 0.5 \leq EX \leq OP \qquad (2)$$

where *EX* is again the exit pupil diameter of the telescope and *OP* the diameter of the observer's pupil, in milimeters. This latter expression cannot be true for all observers because of individual differences in the eye. The telescope size also enters into the expression and in general the closest correlation will be found by observers having small instruments. A thorough treatment of the subject is given in Konig and Kohler[1].

The above considerations apply only to extended objects. A star, on the other hand, appears under such a minute angle that it cannot be resolved, regardless of the magnification used, and the angular subtense is not increased with magnification. An observer therefore only sees a diffraction pattern, and the geometric approach used for extended objects becomes invalid and cannot be applied to point objects. If, for example, the telescope has an overall magnification M, and if the exit pupil diameter of the telescope is matched to that of pupil of the observer, then the diffraction pattern of the star will appear M^2 brighter, as when viewed with the naked eye.

This magnification M cannot be pushed to arbitrary limits, as one must bear in mind that due to diffraction effects of the eye pupil, the diffraction pattern increases with its decreasing pupil diameter. Also, the inhomogeneities in the eye become very bothersome when viewing through an instrument with a very small exit pupil. A lower limit on the exit pupil size is possibly 0.5mm, as also reflected in expression (2) above.

It was shown above that in the case of an extended object the apparent luminosity will decrease if the exit pupil diameter is reduced below that of the eye pupil. In the real situation the sky background acts as an extended object, whose apparent luminosity also decreases with magnification, thus permitting observation of stars dimmer than predicted by some simplified formulae. In fact under ideal laboratory conditions artificial stars down to 8.5 magnitude have been observed by the naked eye due to the complete absence of background[1]. The normal formulae predict a limiting magnitude of about 6 and the improved performance capability is known as "artificial contrast enhancement"[2]. Thus the visibility of stars has very little to do with the Stiles-Crawford effect or the spherical aberration of the eye, as is claimed in older literature[3]. In conclusion, it has been shown that for the detection of faint stars high magnification and hence a small exit pupil is required, while if observation of dim extended objects is the requirement, then the exit pupil size must be matched to the eye of the observer. As these two requirements are basically contradictory, it can be concluded that no single objective/eyepiece combination exists that will simultaneously perform optimally for both applications.



The authors, McDowell and Klee.

The Eyepiece Specification

In order to specify the compensating eyepiece, it is clear that the application of the overall telescope must be defined. In the present case the requirement is to achieve the maximum possible field of view with the exit pupil matched to the observer's eye.

The real field of view (FOV) of the telescope system can be expressed approximately as:

$$\frac{FOV}{2} = \frac{\theta \times fe}{fo} \qquad (3)$$

In this expression θ is the semi-apparent field of view of the eyepiece while *fo* and *fe* are the respective focal lengths of the objective and eyepiece. The effects of distortion are also allowed for through the use of θ instead of tan θ.

In order to increase the real field of view, either θ or *fe* must be increased or *fo* decreased. For the present study and for sound design reasons, the apparent semi-field of the eyepiece will be restricted to 25 degrees, leaving only *fo* and *fe* as variables.

As it is intended that the eyepiece will be suitable for use with a wide variety of telescopes, the value of *fo* is an unknown, but typically the paraboloid will have a relative aperture of f/4, which must be matched by the eyepiece. The relative aperture of the latter is given by:

$$f/number = \frac{fe}{EX} \qquad (4)$$

As we require the widest possible real field of view, *fe* should be as large as possible and since the f/number is a

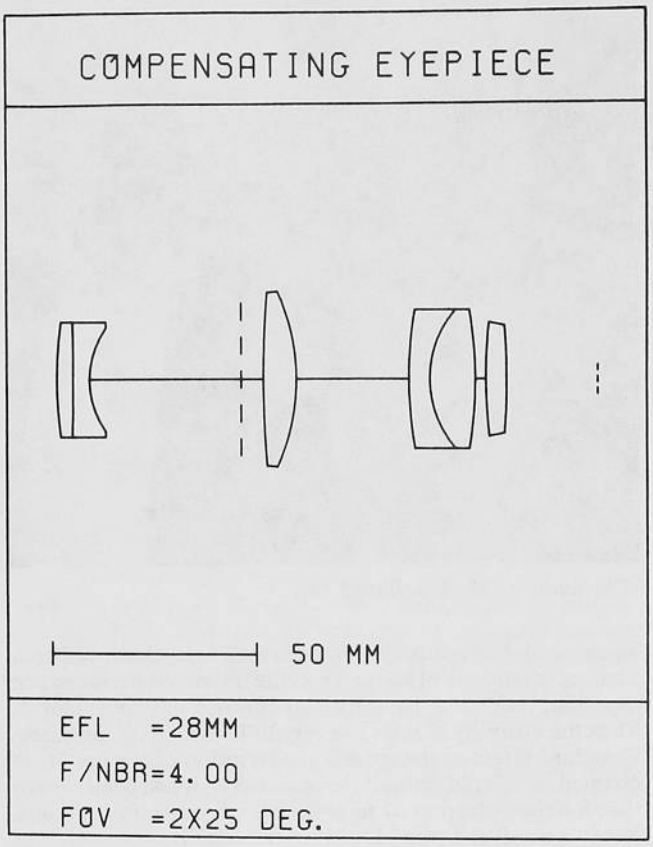


Figure 1

constant (Eq. 4), the exit pupil must be as large as possible. It is generally accepted that the fully dilated eye pupil has an average diameter of 7mm, and matching the exit pupil to this results in an eyepiece focal length of some 28mm (at a relative aperture of f/4).

In order to enable the eye to observer the image comfortably, the exit pupil should be located at a reasonable distance behind the last lens surface, and for the present study an eye-relief greater than 20mm was specified, which will enable eyeglasses wearers to view the field without too much vignetting.

The complete first order specification is given in Table 1.

Table 1
First Order Specification

Eyepiece focal length	28mm
Field of view	2x 25 degrees
Exit pupil diameter	7mm
Eye relief	$>$20mm
Primary mirror	paraboloid (f/4)

With the first order properties fixed, we can now move on to a discussion of the aberrations and try and set sensible limits for these as well. The main aim of our study is to develop an eyepiece that compensates for the inherent coma of an f/4 paraboloid, but in such a study one has to look very carefully at other aberrations as well, especially the lateral colour, as any sizeable residual of this aberration would hardly make it worthwhile to compensate for the coma in the first place. Both coma and lateral color can reduce the contrast in the image to such an extent that even coarse details in the image may become invisible.

For very low light level application, coma is probably the worst of the two because of the inability of the eye to see color under these conditions. It could then be argued that the ability of the eye to resolve details under such adverse conditions is so much impaired anyway that the correction of coma could be regarded as an unnecessary refinement. However, for the eye to see anything at all, it needs contrast in the image, and if the contrast is already reduced as a result of the low light level, one surely does not want to lose more contrast by allowing coma in the system.

Field curvature and astigmatism are related aberrations and their state of correction is still open to controversy amongst optical designers. Some favor a flat tangential field, others a flat sagittal field, while others still, including the authors, would prefer a curved field without astigmatism, provided of course that the field curvature is not excessive. This controversy can to some extent be ascribed to the ability of the eye to accommodate and thereby render the effects of astigmatism and field curvature less noticeable. The accommodation range does, however, decrease with age and, while a young observer of ten years can accommodate over a enormous range of 13 dioptres, a person older than 55 can only accommodate by about 1 dioptre. These stated values are only guidelines as there are again large individual differences. As all age groups can be found amongst amateur astronomers, it would be unfair to the older generation to design an eyepiece that fails to take cognizance of their inability to accommodate over a larger range of dioptres. We therefore decided to design the eyepiece to show zero astigmatism and -1 dioptre field curvature when used with a 6 inch f/4 paraboloid. If used with a larger paraboloid of equal focal ratio, the field curvature will be slightly more negative, because this larger primary mirror will contribute less towards the field curvature compensation, but astigmatism and coma correction will not be affected.

There have been arguments in the past as to whether the spherical and axial chromatic aberrations of the eye should be compensated for by the telescope system, and while there is apparently some evidence that this could be beneficial in some cases, it is also true that the required compensation would vary from individual to individual as there is no such thing as a "standard" eye. Every person is in any case accustomed to seeing objects with the inherent aberrations of his own eyes and the brain can and does compensate for this. We therefore decided to keep the spherical aberration and the axial color as small as possible.

Distortion is the last and also the least important of the aberrations. It does not in any way affect the image quality and is generally inconsequential in visual astronomy, not requiring special consideration.

The accepted resolution limit of the eye under favorable conditions is considered to be about 1 arcminute. With this in mind we can draw up the specification for the aberrations and these are given in Table 2.

The Eyepiece Design

The authors recently concluded a study of some novel optical instruments that contained a zero power optical component for the correction of aberrations[4,5,6]. This class of instruments proved to be extremely versatile and is well suited for the design of eyepieces with large exit pupils.

The design contains, in its most basic form, only four optical elements and is capable of excellent imagery. The only drawback is the fairly large filed curvature. Since in the present case the filed curvature had to be kept below 1 dioptre, we decided to use our basic design in conjunction with a type of Barlow lens. This idea is of course not new, having been suggested by Hartshorn[7] and also by Bob Cox[8].

The detailed lens prescription is provided in Table 3

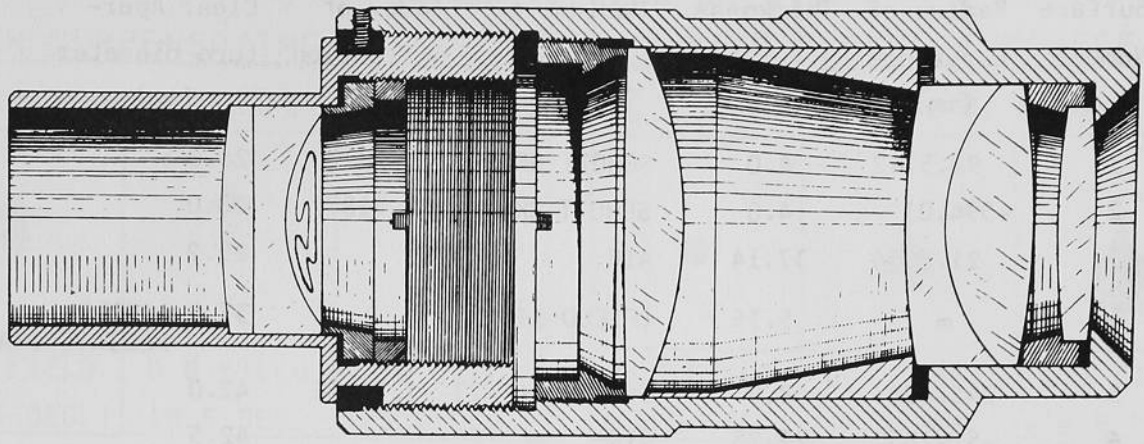


Figure 2

together with manufacturing tolerances. The choice of glass types is by no means unique and those given in the table were merely those used for our own prototype development. Cheaper glass combinations may be used without a significant deterioration in performance but, of course only after appropriate redesign. The cross section of the present optical design is shown in Figure 1 with more details of mechanical construction in Figure 2.

One can easily recognize the negative group on the left of the figure. It is located some 30mm inside the primary focus and magnifies, Barlow fashion, the primary image by a factor of about 1.5 times. This secondary image is formed close to the large single field lens. At this position, the image is not well corrected. This is also not required, as the remaining portion of the eyepiece removes whatever aberrations are not under control so as to deliver a final image consistent with the requirements of Table 2. One aberration that might be noticed at the intermediate image plane is the lateral color, because the field stop is located there, and this might show up a slight coloring of the field stop under higher light levels.

Since this eyepiece was to be evaluated by a number of different amateur astronomers having instruments we know nothing about, a fine focusing arrangement in the eyepiece barrel had been included, so that amateurs having only rack and pinion eyepiece mounts could also take part in the evaluation. The total travel within the eyepiece amounts to some 4mm. The portion of the barrel that slides into the eyepiece holder is manufactured from stainless steel so that it is less easily damaged by the thumb screw incorporated in some eyepiece mounts to secure the eyepiece. It has since been found that a fine rack and pinion focuser allows sufficiently good control and in such a case the in-built focusing arrangement is not required.

Image Quality Analysis

The imaging quality of an optical system can be theoretically evaluated by several methods, such as wave-front errors, the modulation transfer function (MTF), and by spot diagrams, to name a few. Of these the MTF is doubtlessly the most useful and also the most objective, but it is also true that most amateurs will not be familiar with its somewhat abstract concepts. We have therefore elected to show the image quality by means of spot diagrams. However, whereas the MTF describes the image quality in terms of contrast and can be made to take diffraction effects and also the spectral

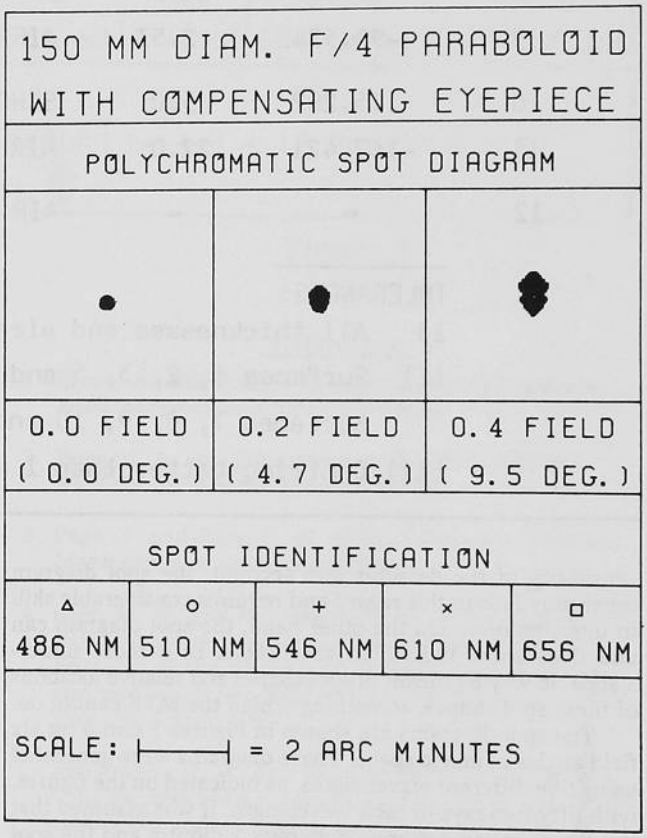


Figure 3

Table 2
Performance Requirements

Spherical aberration	Diffraction limited
Axial color	Diffraction limited
Coma	< 1 arcminute
Primary lateral color ($\theta_c - \theta_F$)	< 1 arcminute
Astigmatism	0 dioptres
Field curvature	< 1 dioptre
Distortion	< 15 percent

Surface Number	Radius of Curvature (mm)	Thickness (mm)	Medium	Index of Refraction (n_e)	Clear Aperture diameter (mm)	
1	98.5342	4.0	SCHOTT SF11	1.7919	28.0	
2	-594.01	4.0	SCHOTT BK7	1.51872	28.0	
3	21.6056	37.14	AIR		25.2	
4	∞	5.35	(FIELD STOP)		37.0	(INTER-MEDIATE IMAGE)
5	242.428	8.0	SCHOTT LaFN21	1.79226	42.0	
6	-51.1832	27.25	AIR		42.5	
7	98.5342	5.0	SCHOTT SF6	1.81265	33.6	
8	25.7854	11.0	SCHOTT LaKN7	1.65426	31.0	
9	-98.5342	2.53	AIR		31.0	
10	115.282	5.0	SCHOTT LaFN21	1.79226	27.6	
11	-167.421	22.0	AIR		26.0	
12	∞	-	AIR		7.0	(EXIT PUPIL

TOLERANCES:

i) All thicknesses and airspaces ±0.1 mm

ii) Surfaces 1, 2, 3, 5 and 6 : 5 fringes
Surfaces 7, 8, 9, 10 and 11 : 3 fringes

iii) Centring better than 1 minute of arc

Table 3

sensitivity of the detector into account, the spot diagram inherently fails in this regard and requires considerable skill in interpretation. On the other hand, the spot diagram can and does show individual aberrations in a more understandable way by means of spot shapes and relative locations of these spot shapes, something which the MTF cannot do.

The spot diagrams are shown in Figures 3 and 4 for six field angles in image space. These diagrams were generated using five different wavelengths, as indicated on the figures, with fifty-two rays in each wavelength. It was assumed that the observer can accommodate over 1 dioptre and the spot diagrams have been generated reflecting this ability.

On axis (0.0 field of view in Figure 3) the image is diffraction limited, as demanded by our specifications on image quality. However, as soon as one moves off axis some lateral color becomes evident by the elongation of the spot. (See 0.2 field and 0.4 field in Figure 3.) This image error will not be visible for these field points, as the elongations of say a star image is less then 1 arcminute. Farther off-axis the spot shapes become more interesting. The monochromatic coma, as indicated by the vertical crosses (546nm), is in all cases smaller than 1 arcminute, complying once more with the specification. Primary lateral color, as indicated by the small squares and triangles corresponding to 656nm and 486nm, respectively, is also less than 1 arcminute because the spot formed by these two wavelengths is smaller than 1 arc minute. Secondary lateral colour is unavoidable and can be measured as the distance between the centroid of the spot at 546nm and the two superimposed spots at 486nm and 656nm, and amounts to less the 2 arcminutes. The gaps that are visible in the spot diagrams are caused by the fact that only five discrete wavelengths were used for the spot diagram generation and in no way reflect the true appearance of the actual image. These gaps however indicate in this case the high image quality inherent in the optical system. If the system were less well corrected, then the individual monochromatic spots would overlap and smear out over the entire spot diagram, thereby rendering the gaps less conspicuous or even invisible because the eyepiece mount will vignette these rays. Also, their intensity would be too low to be preceived by the eye.

For comparative reasons we also evaluated an f/4 paraboloid together with a Plossl eyepiece. This eyepiece was taken from the literature and is fairly well corrected, although only at a relative aperture of f/5 and for a field angle of some 40 degrees. This eyepiece was scaled to render a focal length of 28mm and to give a field of 50 degrees. The spot diagram of this system is shown in Figure 5 where the scale had to be increased six-fold over that of Figure 3 and Figure 4 to allow presentation within the confines of the drawing. The

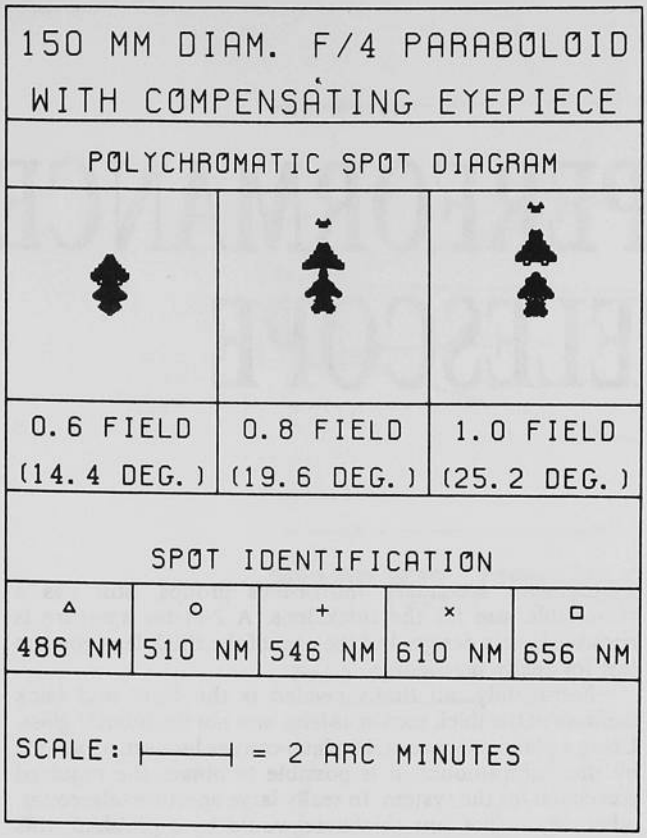


Figure 4

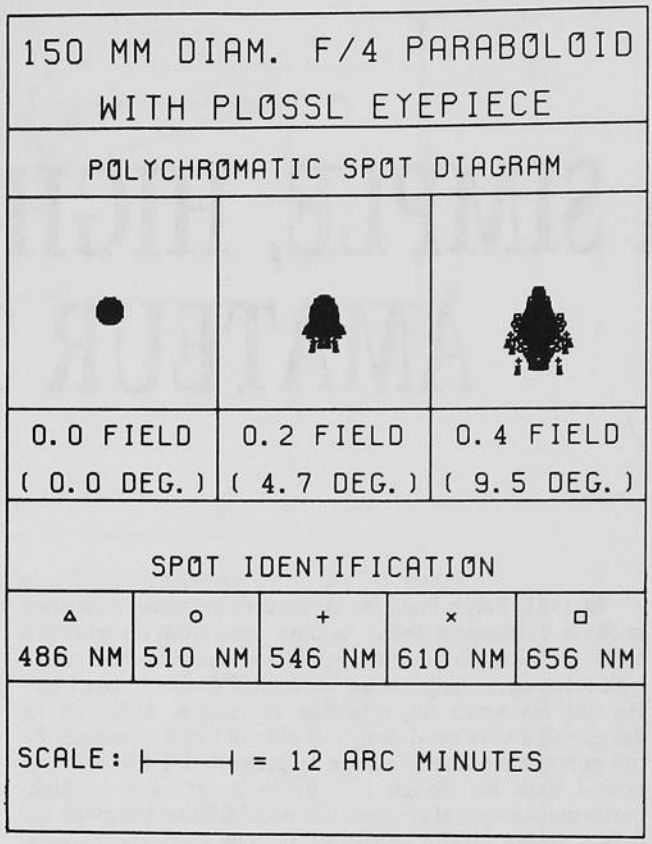


Figure 5

scale therefore now represents 12 arcminutes. As can be seen from Figure 5, these spots are enormous compared to the spots in Figure 3 and 4, and for this reason only an evaluation up to 9.5 degrees off-axis has been carried out. We have included this mirror/eyepiece combination only to show once more that to buy an eyepiece simply because it has a good name does not guarantee that is will perform well in your system.

Constructional Notes

The tolerances given Table 3 are not particularly stiff for a well-equipped optical workshop. The amateur telescope maker, on the other hand, will find the construction less easy, since he has to make the necessary proof plates himself, which greatly adds to the compexity of the inherently simple task. For this reason alone we do not believe that relaxing the tolerances would make the task any easier. If there should be some enterprising amateurs who feel competent enough to tackle such a project, we would only be too willing to redesign the eyepiece for different focal lengths and with perhaps cheaper glasses, provided that they address their communication through Bob Cox (305 Linda La., O'Fallon, MO 63366). In this way the wishes of the amateur fraternity are served best.

Summary

Two prototypes of the eyepiece have been constructed and have been evaluated by amateur astronomers in both the United States of America and the Republic of South Africa. Reports from these astronomers have been very positive[9] and we have received many inquiries as to where such an eyepiece could be purchased. It is hoped that the publication here of the lens details will encourage amateurs to either manufacture the lens themselves or to have it constructed for them at one of the companies that specialize in optics for astronomers.

References

1. Konig, A. and Kohler, H. 1959. Die Fernrohre und Entfernungs-messer, Springer-Verlag.

2. Weigert, A. and Zimmermann, H. 1960. ABC der Astronomie, Werner Dausien Verlag.

3. Page, T. and Page, L. W. 1966. Telescopes: How to Make and Use them, MacMillan.

4. Klee, H. W. and McDowell, M. W. 1985. Lens systems incorporating a zero power corrector: Part 1. Principle of the design and its application in large aperture, moderate field of view optical systems, Proc. SPIE 554, 406.

5. McDowell, M. W. and Klee, H. W. 1985. Lens systems incorporating a zero power corrector: Part 2. Objectives and magnifiers for night vision applications, Proc. SPIE 554, 413.

6. Klee, H. W. and McDowell, M. W. 1985. Lens systems incorporating a zero power corrector: Part 3. New four-element microscope objectives with flat field or high power, Proc. SPIE, 554, 228.

7. Ingalls, A. (Editor). 1955. Amateur Telescope Making, Book 3, Scientific American.

8. Cox, R. E. private communications.

9. Cox, R. E. 1985. Proceedings of the National Astronomy Convention, Tucson, 40.

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A SIMPLE, HIGH-PERFORMANCE AMATEUR TELESCOPE

In 1981, Ralph Field (an Australian amateur) described in *Sky & Telescope* a design he developed from a suggestion by D. D. Maksutov in his original disclosure on Maksutov-type telescopes. Ralph is not an optical designer, but I am. He did his work on a pocket calculator. Although he developed a very good design, it did not begin to realize the full potentials of the telescope he presented. I will describe how I took his design and made it into a very high-performance optical system with no additional components. It is a design ideally suited to amateur telescope makers, especially those who build large-aperture telescopes.

The basic configuration consists of a fast, spherical primary mirror (around f/2.0) that sends light to a spherical secondary mirror. Between the mirrors is a single, thick meniscus lens seen twice by the light path. This lens fully corrects the large amount of spherical aberration coming from the primary mirror and corrects for coma without introducing any axial color.

Ralph Field's design had a slow-speed primary mirror and a thin meniscus lens. I found a thick lens made all the difference and allows the design to work well with fast primary mirrors. My faster speed system allows a tube length half that of the tube in the design by Field, though a penalty for this is that the parameter tolerances and assembly tolerances in my instrument are tighter than on the Field instrument.

I don't do a lot of observing and live in a suburban area with a lot of light pollution. So I figured what the heck, if I'm not going to use a telescope that much, why not make a one intended for really high power? The planets and Moon are bright even on nights when streetlights wash out many deep-sky objects. With this in mind, I designed and built an f/18 telescope of 10 inches aperture. I use it most often with a 2-inch focal length eyepiece. It is really wonderful to get high power and a long and comfortable eye relief at the same time.

I have a lot of eyepieces, but even the highest power I'm ever likely to use still has a good eye relief because of the long focal length of the telescope. A further consequence of the f/18 speed is that the obscuration by the secondary mirror is significantly smaller than that found on any commercial telescope (about 20 percent of the primary diameter). This is a positive feature for any instrument to be used for planetary observations where all details are of low contrast.

A final plus to this design, aside from the obvious one of high performance with no aspherics, is that it can be scaled up to really big apertures. A 20-inch aperture, with 1/5- or 1/6-diameter secondary mirror-lens groups, still has a reasonable size for the thick lens. A 2-meter aperture is possible in this design, but the cost of the thick lens goes up fast for really big sizes.

Fortunately, all that's needed is the front and back surfaces of the thick meniscus lens, and not the interior glass. Using a plano-concave and a plano-convex lens set, separated by the right amount, it is possible to obtain the required correction for the system. In really large aperture telescopes, where excessive lens thickness would be a problem, this approach makes the design practical.

If I were doing this project over, I would do it somewhat differently. I think that if the final speed is made faster, like f/12 to f/15 for the same f/1.9 primary mirror, (which would mean a somewhat larger obscuration), then the front and back radii can be the same. In the present design they are slightly different.

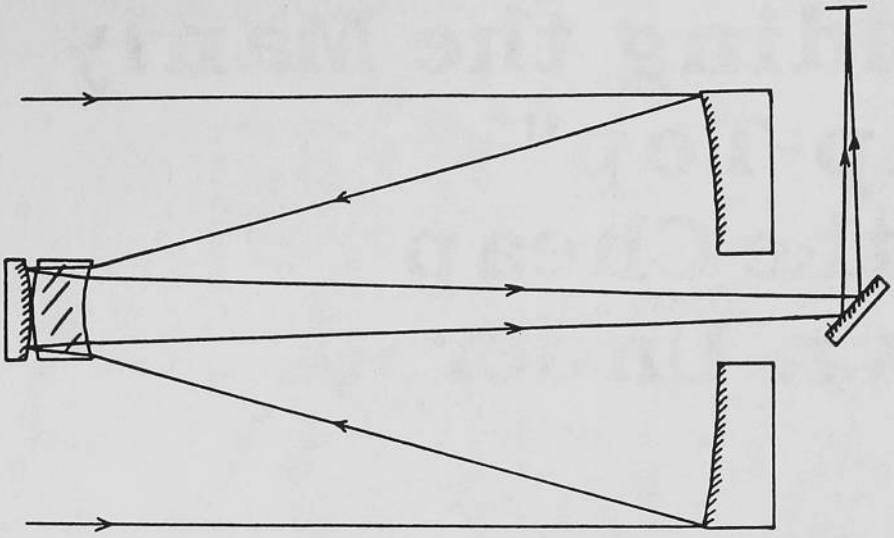
Specifications for the 10-inch are:

Parameter	Dimension
Diameter primary	10.000
Radius	−38.000 ±0.200
Distance to lens	15.578
Glass type (BK-7)	1.516800
Diameter lens	2.000
1st Radius	2.866 ±0.002
Thickness	1.2996 ±0.005
2nd Radius	2.937 ±0.002
Distance to secondary	0.000
Diameter secondary	2.000
Radius	6.900 ±0.050
BFL	24.500
B	9.000

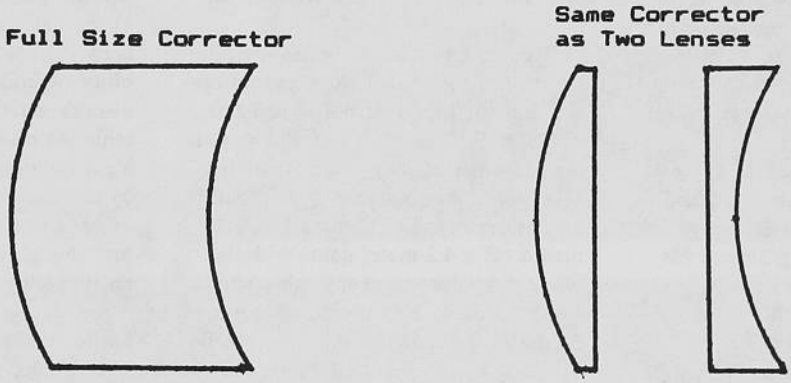
All dimensions are in inches. BFL is the distance from the first lens surface to the final focus, and B is the distance from the vertex of the primary to the final focus.

The tolerances on the lens radii are much looser than the table implies, providing both differ in the same direction. As in a full-aperture Maksutov, the difference in the radii is most important. Note also that the convex surface of the lens is in contact with the convex surface of the secondary — no air space should exist here.

Perhaps one of the most critical parameters is the centration of the secondary mirror relative to the primary mirror. Because of the speed of the primary, this ideally should be held to 0.001", although you could probably live



SHAFER MAKSUTOV–CASSEGRAINIAN
(All Spherical Optics)



with a plus or minus 0.002''. This seems very severe, and it is, but note that the SCTs on the market have similar high-speed primaries, and they hold alignment relatively well in transportation. Besides, a quick tweek of the secondary cell will bring back any loss of alignment.

The path of the edge ray, on axis, as it goes through the system is as follows:

Surface	Ray Height
1	5.0000 inch
2	.9208 inch
3	.8558 inch
4	.8124 inch
5	.8113 inch
6	.6829 inch
7 (image)	.0000 inch

To find the diameter of the optics, double the ray height.

The design is diffraction-limited throughout most of the visible spectrum on axis and is limited in the field by higher-order coma and lateral color. Considering the fast primary mirror, the lack of aspherics, the small correcting lens, and the small number of elements, it is remarkable that the design is as good as it is over a small field of view.

The performance starts degrading near the edges of the field of a 20mm focal length eyepiece, but I have compared this design to designs for Schmidt-Cassegrains and Maksutov-Cassegrains with an aspheric touch-up on one of the sufaces and have found that this new design is superior to them. It would, of course, get even better with a primary mirror slower than the f/1.9 value I chose for the prototype.

I think this new design is ideal for amateurs. It offers better performance than what is commercially available and can be scaled up to really large sizes. If you else should care to construct a telescope of this design, I would be happy to share my experiences with you.

David Shafer
D. Shafer Optical Design, Inc.
56 Drake Lane
Fairfield, CT 06430
(203) 259-4929

Editor's note: At last year's Riverside Telescope Makers Conference, I had the privilege of including in my paper on all-spherical optical systems for the amateur, material presented in the preceding article by Dave Shafer. Response was high. Several of those present who had been planning large aperture Cassegrain or Dall-Kirkham telescope expressed an interest in using the Shafer design instead.

It has long been my hope of making all-spherical high-performance telescopes designs available to TMs because it is relatively simple to fabricate a spherical mirror to 1/50-wave. In contrast, a good 1/16-wave aspheric is a task for a master optician. Unfortunately, many all-spherical designs involve lens elements in combination with mirrors, so relatively few amateurs have found the excitement and expanded field of instrumentation available in this approach. Those who have built them have been very pleased with both the challange of lens making and the performance of the resulting instruments.

— R.E.C.

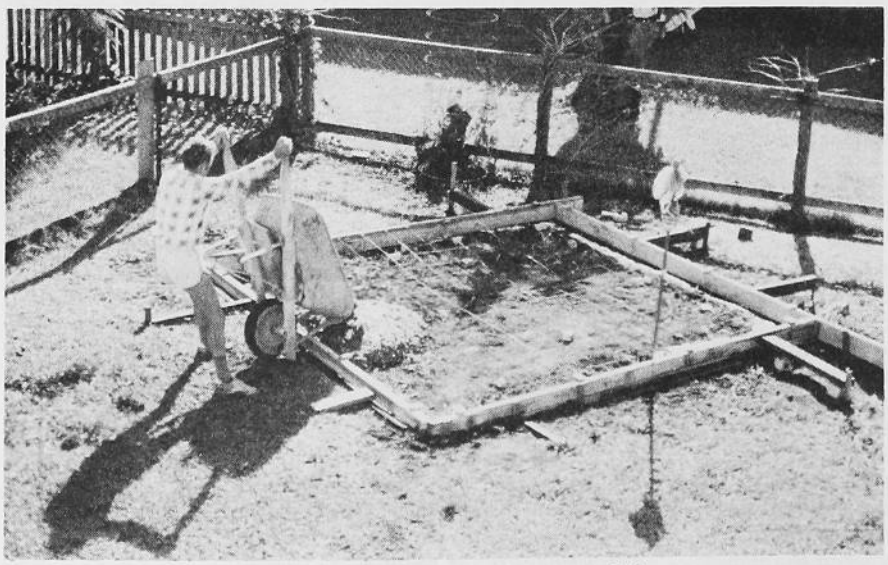
Building the Manly "Flip-Top" On the Cheap Down Under

There are many ways of housing your telescope. Whether they are elaborate domes or simple roll-off roof designs, such housings must be practical to operate, and must protect the instruments inside from the weather.

You can find such housings in backyards and remote mountain tops, and somewhere nearby you will always find the owner/builder sniffing around his telescope. When you ask how he built the thing, you will probably hear of how it was thought it up and why, when, and how it was built. Then he'll launch into something like: "Would you like a copy of my plans since you like my setup....?" These words are to be expected, because most amateur astronomers take pride in what they do, so I've decided to let you know how I built mine, and the plans are here for all to see.

Because I had too little room on the site to roll the roof back, I had no option but to "flip" the roof -- and this works well. This design by the way, is the only one of its type in Australia. This is not the first time I have built an observatory. Some years ago, I finished off a 4.2-meter dome with double sliding shutters at my other site at Golden Beach, 120 kilometers north of Brisbane. Here, where the skies reach Mv=6.3, I use a one-ton 12.5-inch f/6 Cave reflector mounted on a huge German equatorial mount that I also built at a local engineering shop. But that is another story.

In my experience the size of an observatory depends on a number of important points:
1) the balance in the owner's checkbook, 2) the site's location and availability of building materials, 3) the owner's handiness with power and hand tools, 4) rules and restrictions of the local building authorities, and
5) the size and type of telescope(s) to be used at the site. For myself, I had just enough money and skill to put it up, the site was right, and the supply materials were at close hand. My trade background as a boilermaker and welder would help, too, and I got permission from the local authorities to build. The telescope I intended to house was a common 20cm f/6 Newtonian.

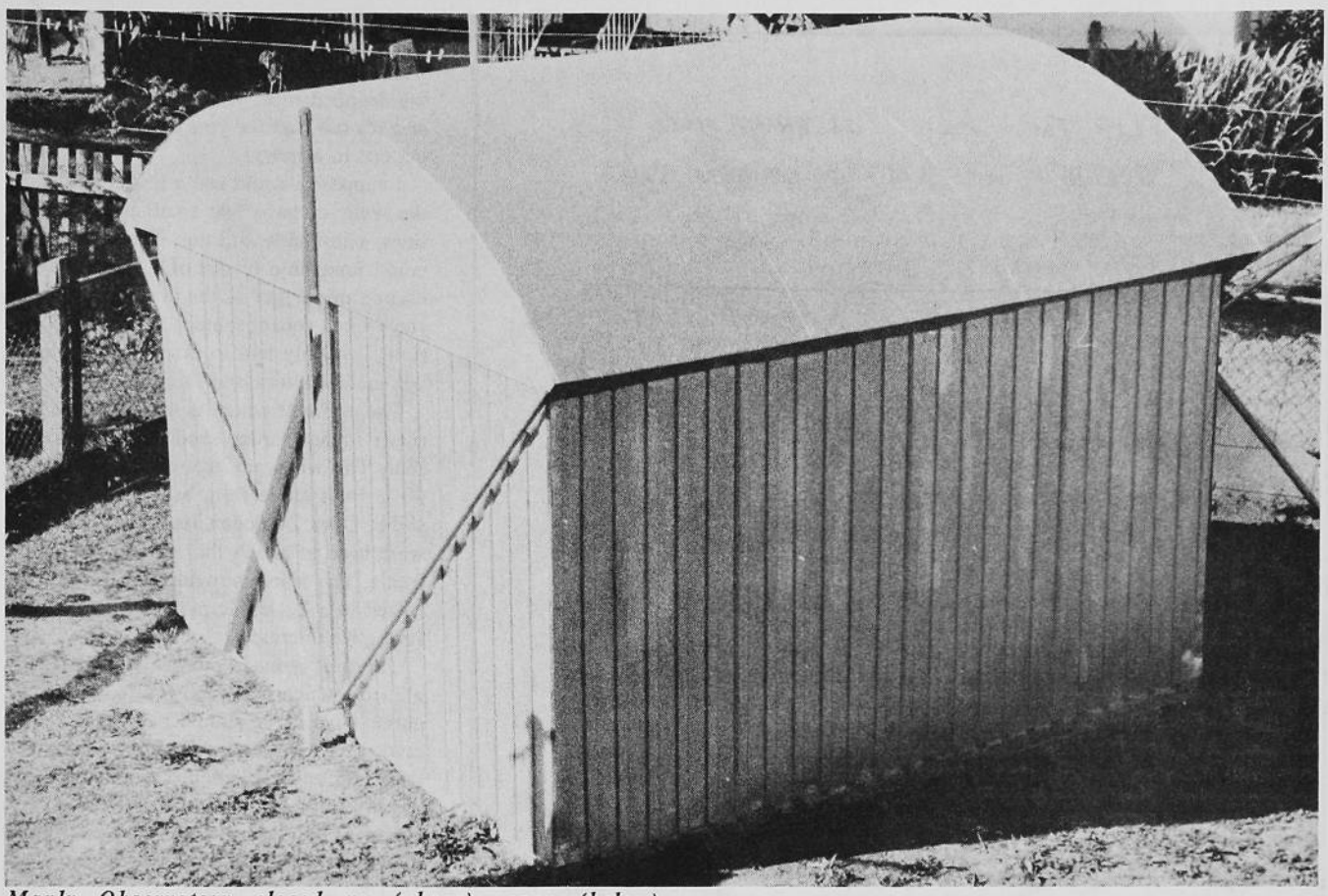


Construction begins with pouring a concrete slab.

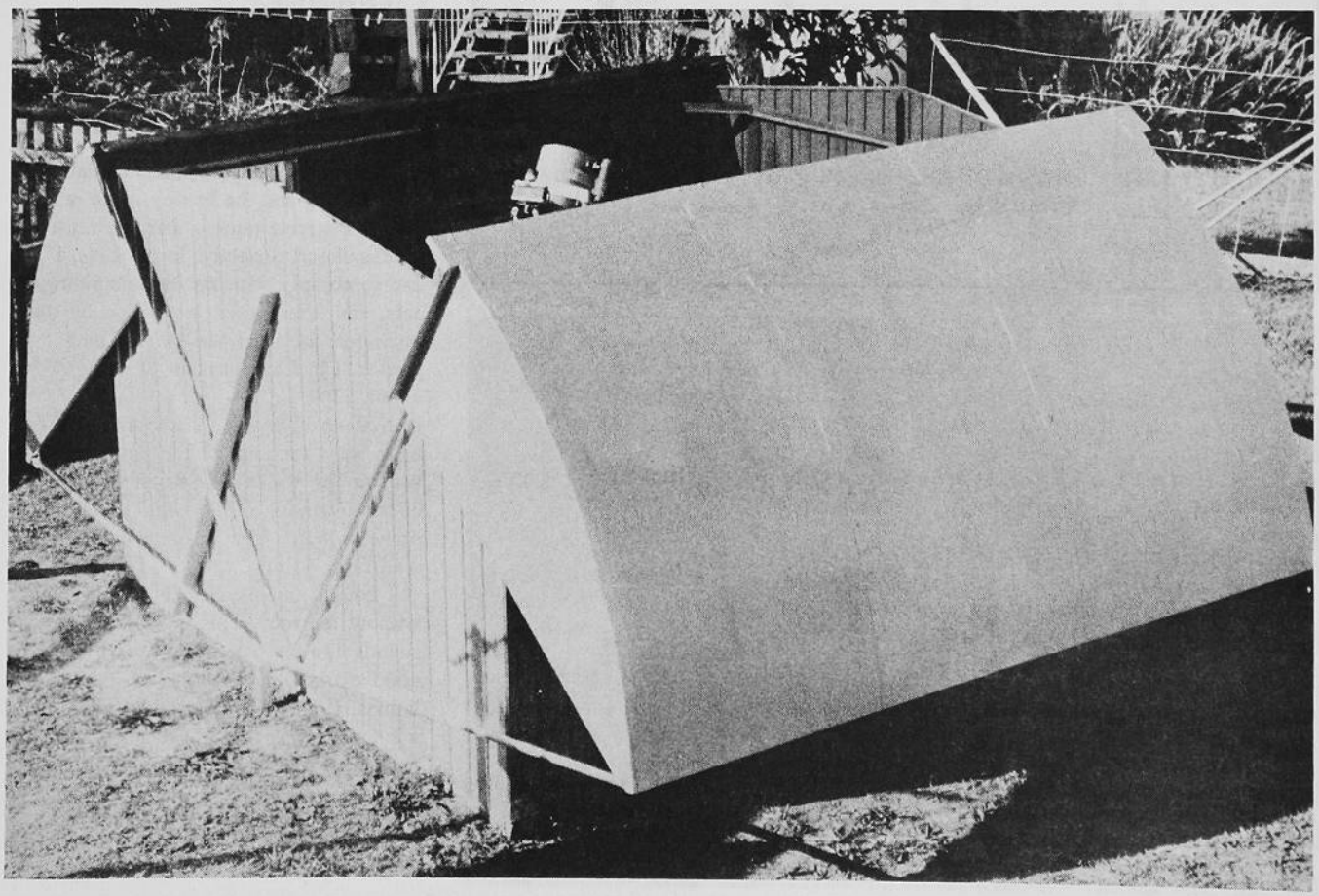
General Idea of How It All Works

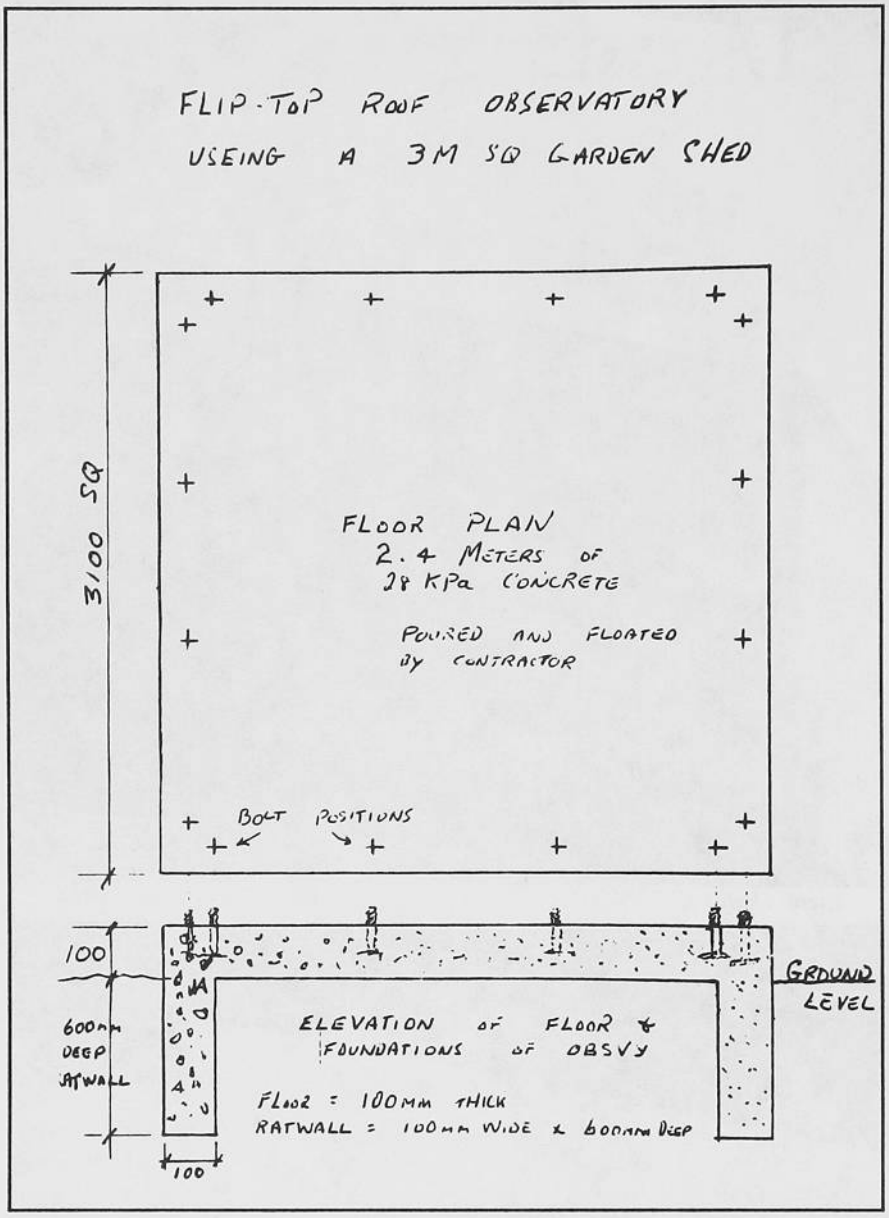
Because I had no room in my yard to roll back the roof, the flip-top was a necessity. The pictures in the article will give you a better idea of how the arrangement works than I can describe. The halves can be opened to any desired aperture. Although we have had some nasty storms here, not one trace of water has found its way in. Liberal overlap where the two halves meet has worked well, and proven to be quite practical. A rubber seal prevents water from running back into the observatory. The roof is lowered via a 4mm steel cable attached to a 5:1 hand-operated boat winch, but I plan to install a 12-volt DC geared motor.

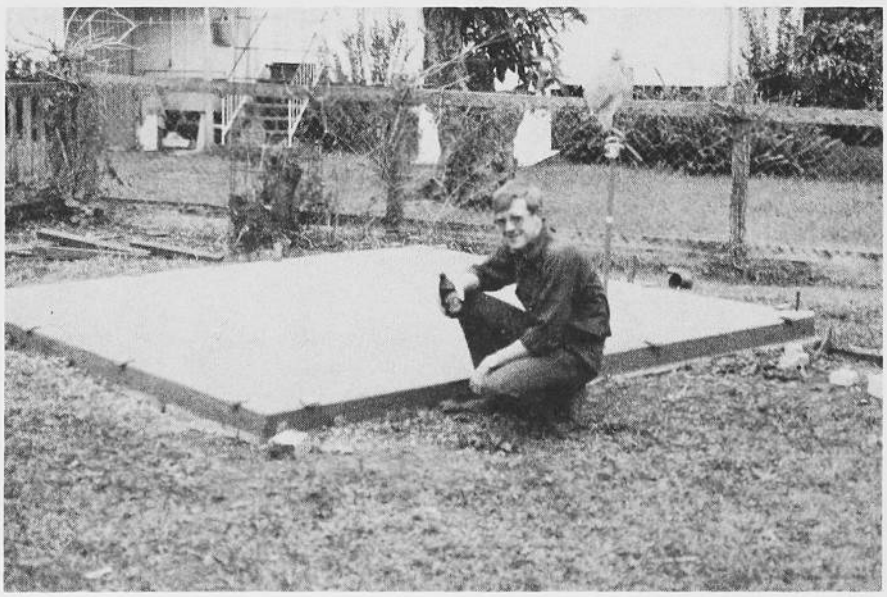
One of the drawbacks of the flip-top is that even though I have a sliding door to get in or out, when the roof half on the door side is down, getting



Manly Observatory closed up (above); open (below).







in or out of the observatory is a chore -- unless you can limbo or crawl under the dropped roof, you will not get in -- and it's too bad for you if you want to get out in a hurry!

I suppose I could use a ladder to scale the walls or have two small trampolines, one inside and out. That way, I could jump into or out of it, but the telescope might get in the way. Anyhow, since I can squeeze under the dropped roof, I've only had to raise the roof for tall male visitors and ladies.

The entire structure is made from a 3-meter-square garden shed minus its flat roof. The walls are supported by 40 x 40 x 4mm angle iron, as the sketches show. Over 24 dozen steel 5/32" rivets were used to attach the steel to the shed frame. The whole structure is firmly bolted to a 2.4 cubic-meter 28 KPa strength concrete slab.

The roof is made out of the same angle iron which I cut and formed into a curve. This curve should have been made at a proper workshop, but since I thrive on any challenge, I decided to put my trade into practice. After some weeks of hard work, it all paid off. The total cost was $1200.00 Australian.

Construction

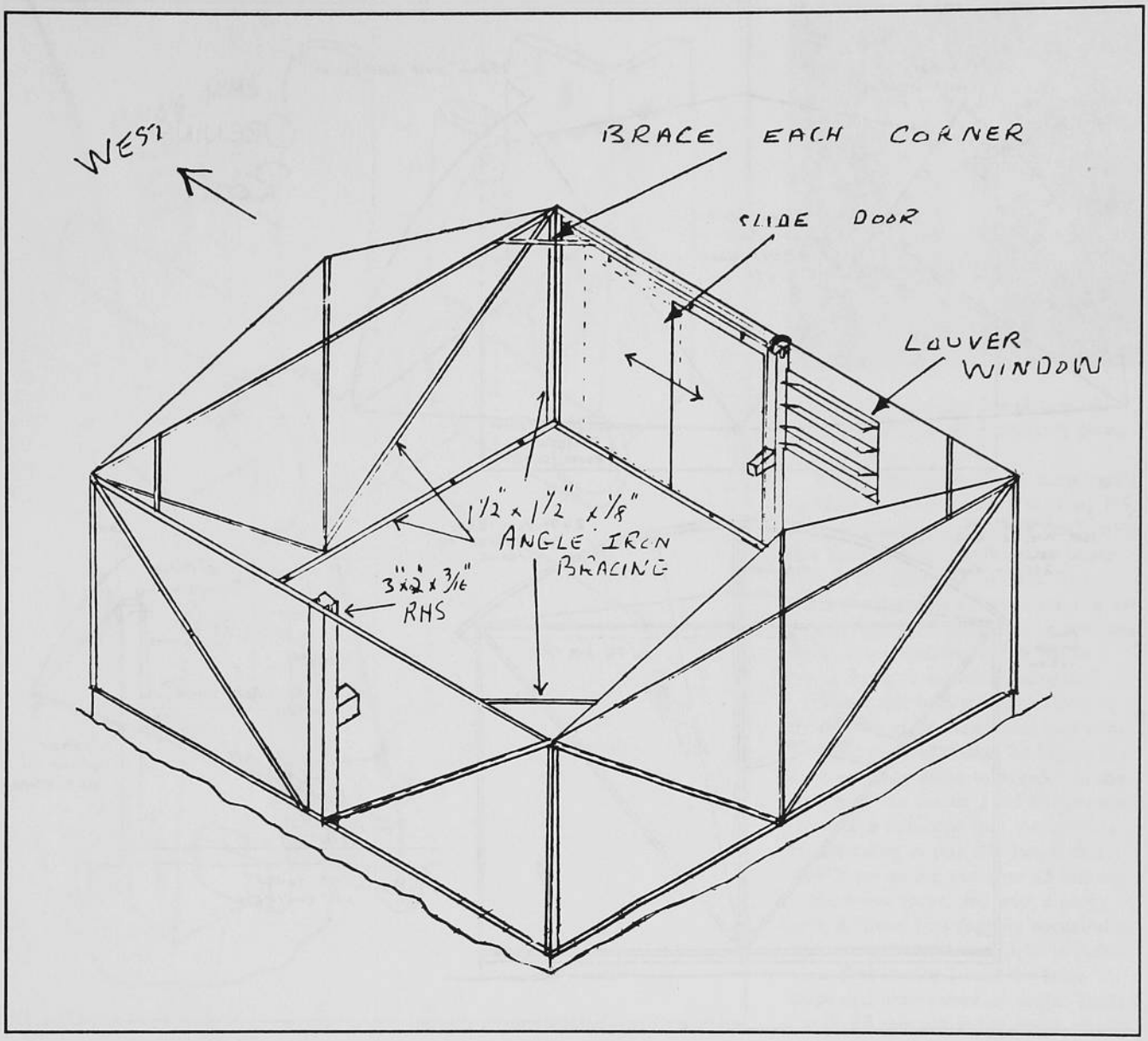
Construction of any observatory, according to those who have built one will agree, is not limited in size or design, except by the checkbook. And that will have the final say.

Having selected the site, foundations must be dug and the boxing made ready for the concrete pour -- and this must be calculated correctly. In my case, I had to comply with the local building acts, and after initial inspection by the inspector, the floor was poured and floated. I had a contractor do it for about $300.

Sixteen hi-tensile, 12x150mm BSW bolts were set prior to the pour. These became the wall's lock-down system. A 25mm-overhang of the wall sheeting prevents water from seeping under the wall/floor joint.

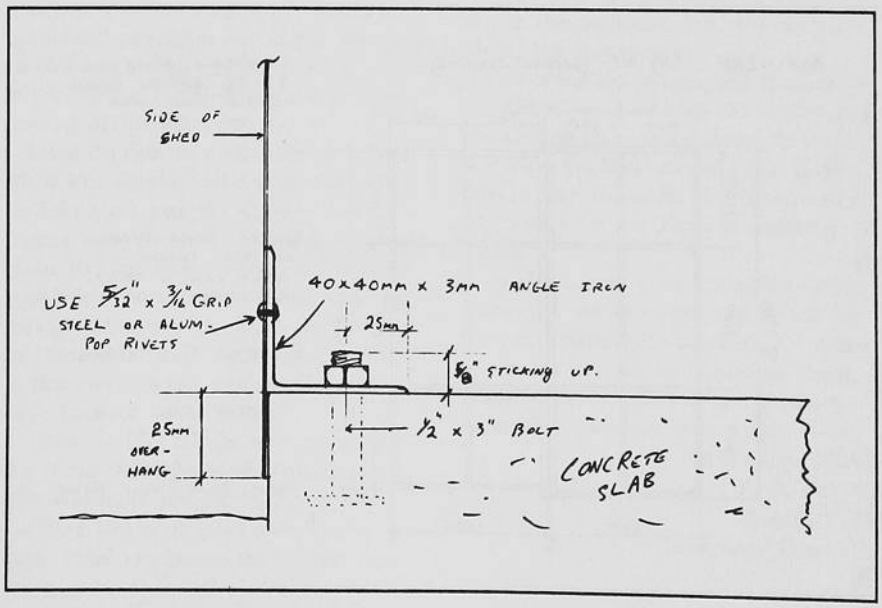
I bought the shed in kit form, but without the roof. This is harder than it sounds. On the day I bought it I had a good workout in observatory public relations. I am quite proud of the fact that not too many people have ever gone in and asked for a garden shed without a roof.

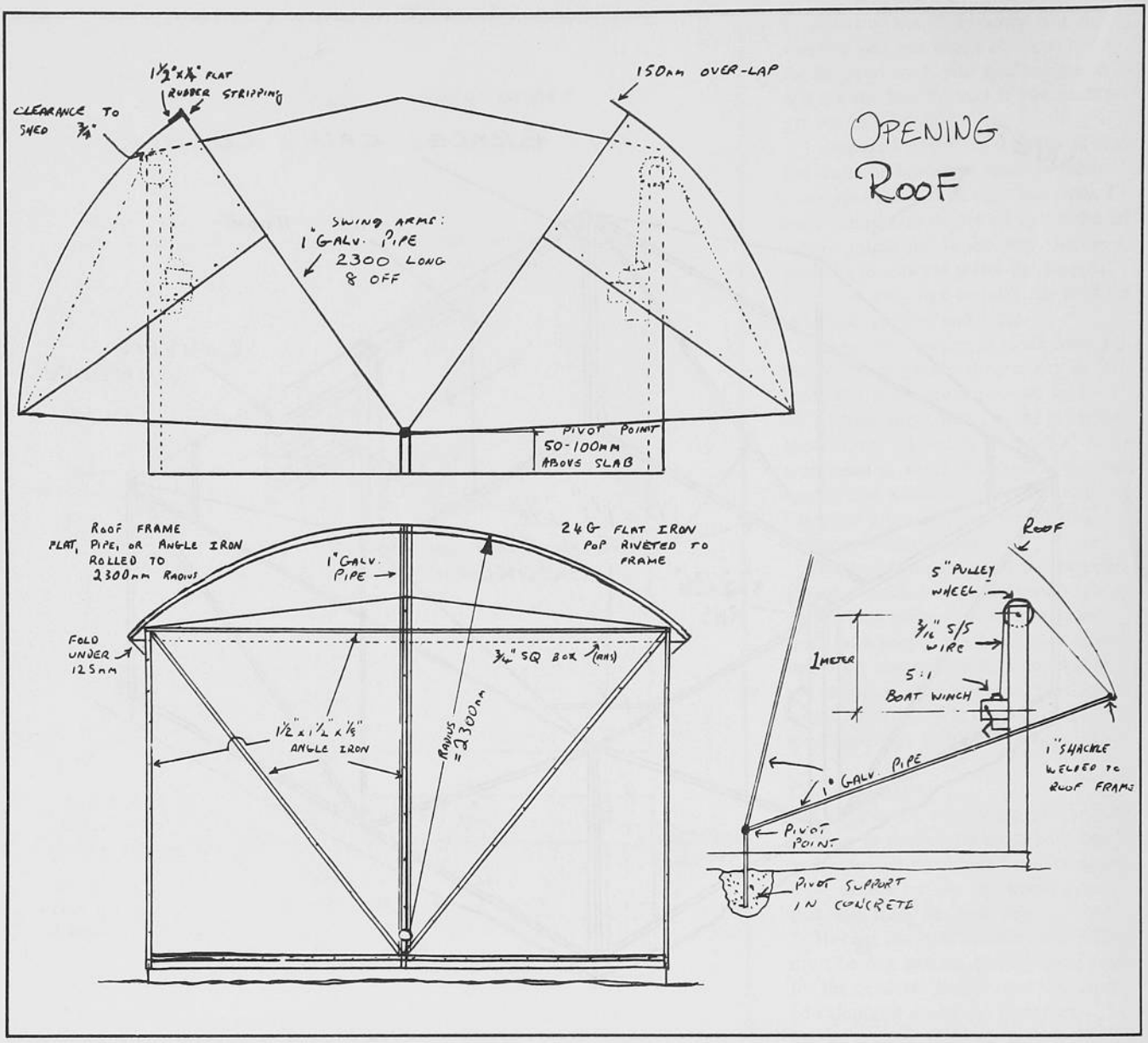
Jim Barclay inspects the newly-poured concrete floor.

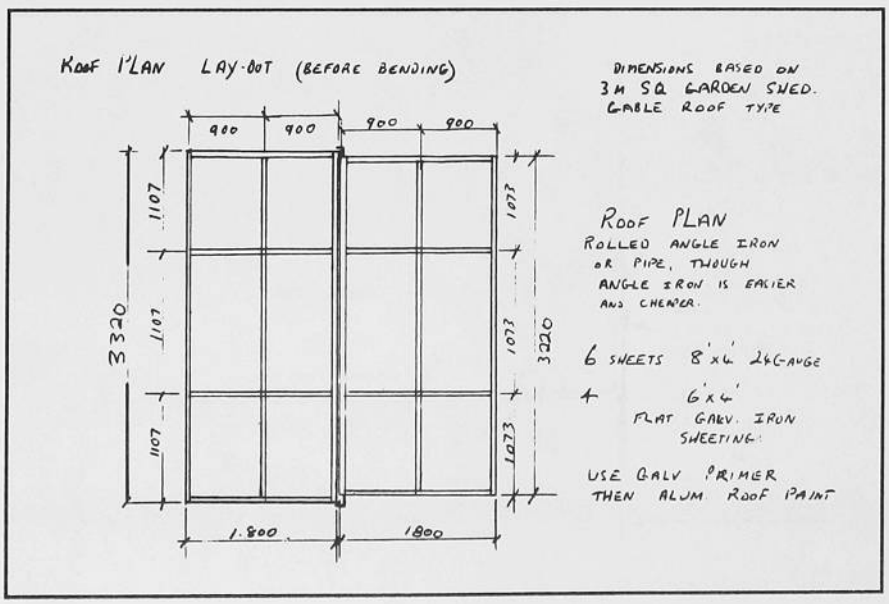


Attaching the steel iron to the walls is quite simple. Just measure and cut to suit. You may want to use box section instead of angle iron; it doesn't matter which you use so long as the walls are strengthened enough. You can use either aluminum or steel rivets, though the latter are stronger. After all riveting has been done, go over with some sealastic putty and cover up each rivet; you may otherwise find rainwater has gotten in after the next strom, or worse, discover your building has rusted after a year or two.

My advice to astrophotographers is design the building so the roof slides (or folds out) to the north and south. This way you will have a slit that runs east-west, and this makes it easier for the scope and its camera(s) to follow an





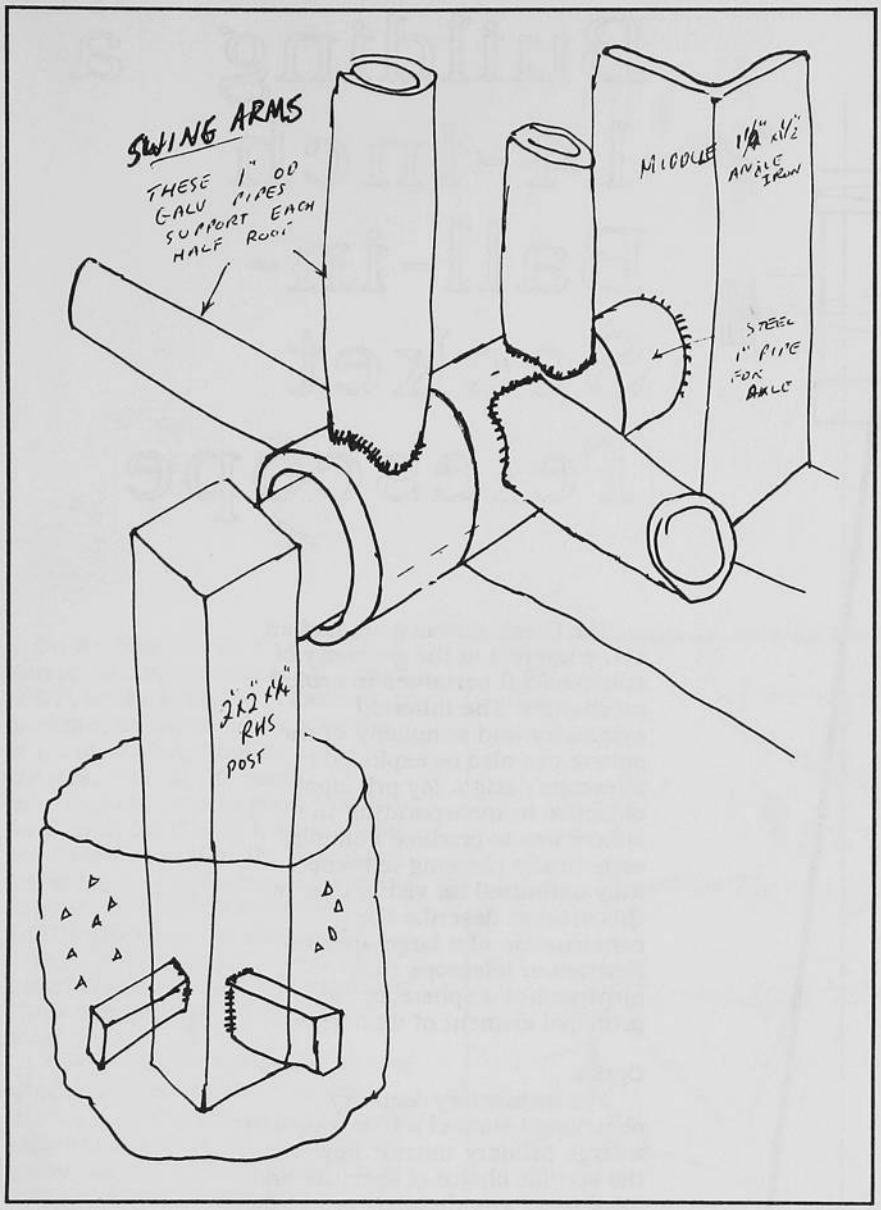


object across the sky. As for size, don't go under three square meters. As we all know, comfort equals usage.

As with all observatory shed designs, during the construction phase, it is a good idea to have a liberal supply of emergency liquids on hand. Sometimes it so happens that one gets halfway through a chore, and that mean-looking emergency supply cooler is watching you. I have found that if you look at it long enough, the lid will suddenly remove itself, and the emergency fluid will suddenly engulf one's lips.

The Roof

Constructing the roof for this type of housing was not only intolerable but a damn-side difficult, mainly because I did not form the curve by machine, but ac-

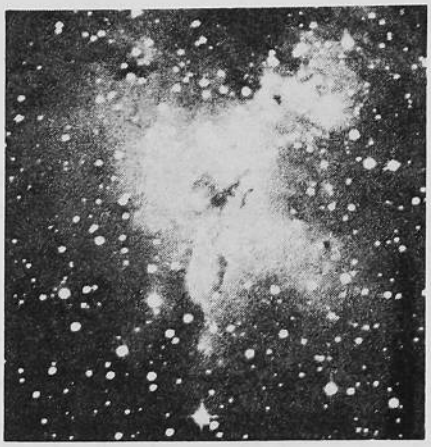


tually made small V-shaped cuts every 150mm on the flange of the angle iron, and then bent the steel around to fit the full size pattern of the curve marked on the slab under my house. Most houses in Queensland are on stilts, not only to let the air circulate and keep the interior cool in summer, but also so you can work and play or party on no matter what the outside weather may be. I build telescopes and observatories under my house. Some day I may forget that there is a house floor above me and find that I have nailed the structure to that floor -- but I doubt it.

To form a curve, particularly in steel, seek out a reputable workshop where they can bend the stuff. But you must have all your measurements true first. If they aren't, then you are to blame and you'll have to have the work done over again, and pay for it twice, too. Be careful and always get someone to check the measurements before you go trotting off to the workhop.

Once the ribs were formed and welded, it was simple matter of adding the straight steel sections. Finally the frames were finished. Lifting them into place was not easy, even though I had man help. The wife was armed with that mean-looking cooler, which didn't help us "bronze aussies" thinking what was in that cooler while our minds should have been on other things.

Once the roof frames were up, sheeting it out in 24-gauge flat galvanized iron was quite simple. Rivetting and caulking was completed over 3 to 4 days. Final touches to the interior and



the electrics saw the completion of what has now become a talking point amongst the yocals.

A shed like this could be started and finished in about a month working full time, but since most people don't have that time to spare, working on weekends is the only way to do it. The thing to remember is: whatever you intend or start to do, make damn sure you finish that objective. If the job is worth doing, it is worth doing well.

Within this bold structure stands a humble 20cm f/6 Newtonian that is no different from any other, and since my skies are only down to Mv=5.0 in the east up to the zenith, I did not put too much of a telescope into the building. Photos taken at this site reveal that stars begin to fog out after 45 minutes at the prime focus, and with a piggy-backed 50mm lens fogging occurs after 15 minutes because the light pollution here. That is why I built the large scope and observatory up north. There I can do 90 minutes at the zenith and 45 minutes over the township of Caloundra, in the northeast. Yes, we can view M-31, but just barely.

Power for the telescope is from an ordinary 80-amp-hr 12 VDC battery and has electric Dec via a homemade drive corrector. On both scopes I use a Mathis 10-inch worm for the 20cm, and 14.25-inch for the 32cm at Golden Beach.

In all, learned a lot during the contruction. I am now readying myself for the next challenge: our club's 5M dome at another site on the Sunshine Coast, where again the stars of the southern hemisphere whisper their magic to all.

Jim Barclay, FRAS
P. O. Box 40
Manly, 4179
Queensland, Australia

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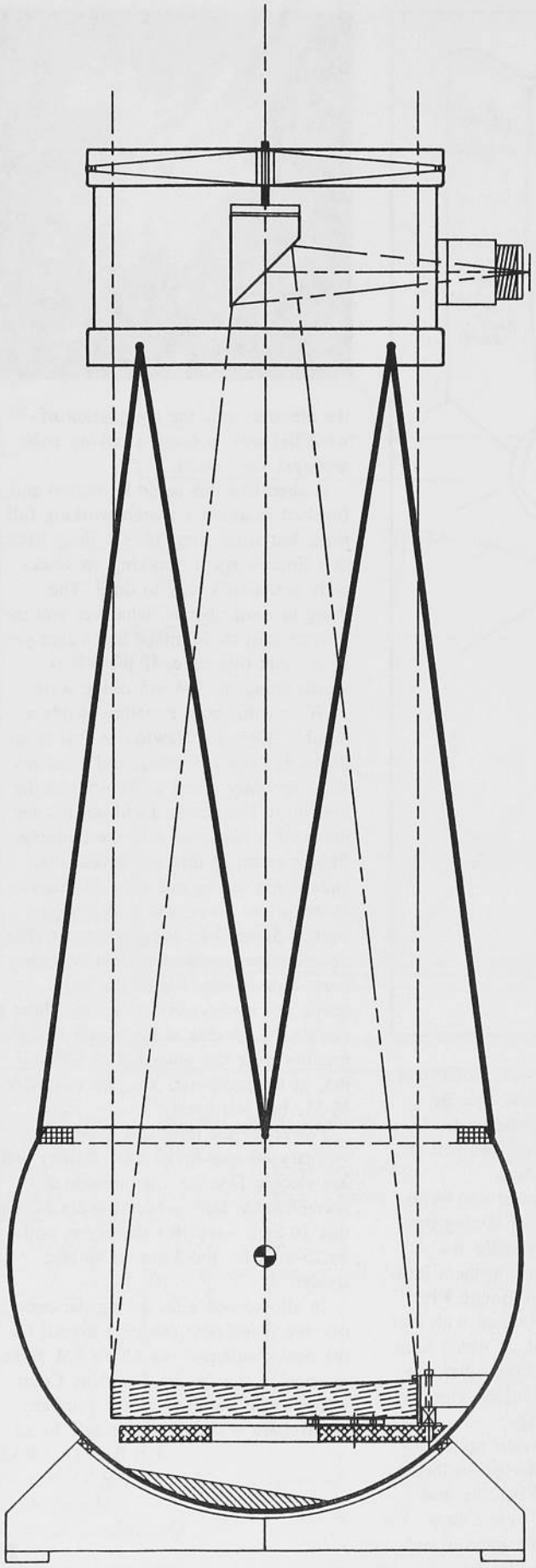


Building a 14-inch Ball-in-Socket Telescope

The Greek astronomers had an acute interest in the geometry of spheres as it pertained to orbital mechanics. The inherent symmetry and simplicity of the sphere can also be exploited in telescope design. My principal objective in incorporating the sphere was to produce a simple, esthetically pleasing telescope fully optimized for visual use. In this article I describe the construction of a large-aperture Newtonian telescope that incorporates a sphere as the principal element of its design.

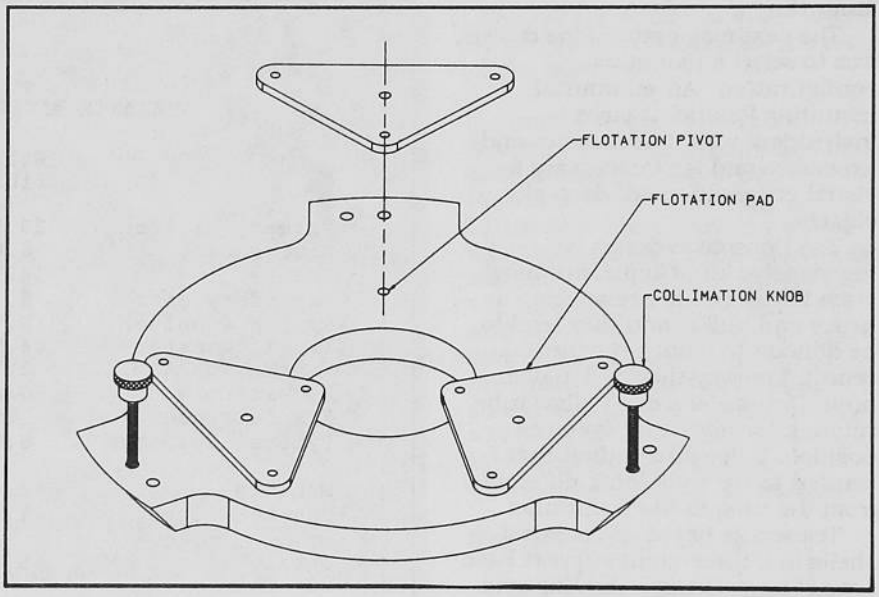
Optics

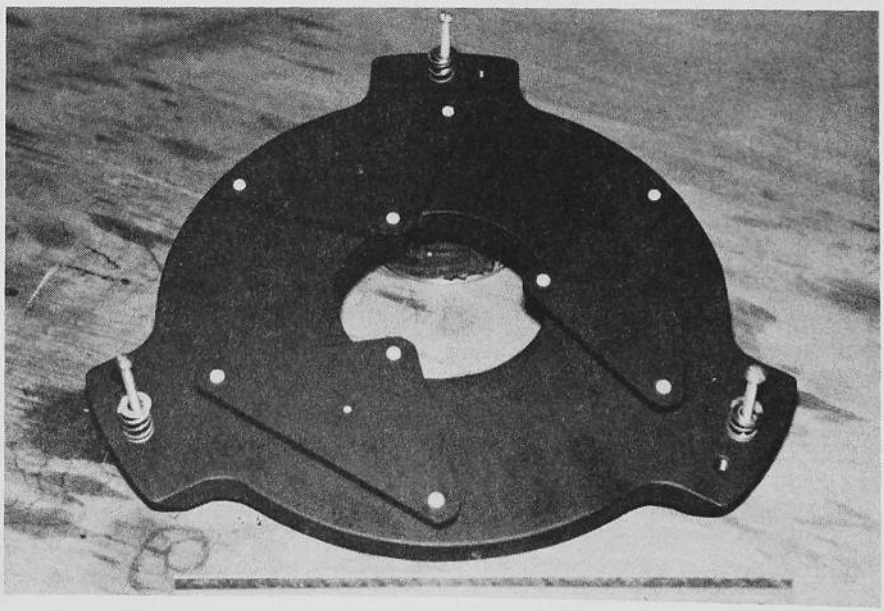
For satisfactory deep sky observing I wanted a telescope with a large primary mirror; however, the specific choice of aperture and focal ratio was dictated primarily by cost, transportability, and focal length. At present there is a large price jump from 13" or 14" mirrors to mirrors of 17.5" aperture. Not only are the smaller mirrors less expensive in total dollars, but they also offer a sizable price advantage in terms of dollars per square inch. For my telescope, I felt that the focal length of a 17.5" f/4.5 mirror was a negative factor. Regardless of the design, the 79" focal length of 17.5" f/4.5 mirror necessitates a ladder to reach the eyepiece, which can be a major nuisance. Furthermore, the weight and bulk of a 17.5" instrument precludes easy one-person portability unless the instrument is broken down into many separate modules, which isn't practical with this design.

On the other hand, a 14.25" f/4.5 mirror has a nominal focal length of 64", so the eyepiece is low enough to eliminate the need for a ladder or an observing stool for most viewers, even at the zenith. This mirror is also a very good match for 32mm focal length wide-angle eyepieces. I felt that the observing advantages of a 65-degree apparent field of view, with a true field of 1.25 degrees and an exit pupil of 7.1mm at a magnification of 50X would provide a very nice setup for observing extended deep-sky objects.

Also, a 1.62"-thick 14.25" mirror weighs only 21 pounds, making one-man portability an achievable goal. In summary, the 14.25" f/4.5 mirror seemed to be the best bet in terms of adequate aperture, excellent cost/square inch, focal length suitability for comfortable viewing, and reasonable size and weight for transportability. Another good choice would be a full thickness 12.5" f/5, which shares the advantages above and would offer somewhat reduced coma.

I selected a 3.1" minor elliptical diagonal mirror with an enhanced silver coating for this system. The special coating gives an 8 to 10 percent increase in image brightness, which I feel is worthwile benefit for the modest price premium. When used with a 3-inch high focuser, this diagonal gives fully illuminated field about 0.50 inches in diameter. This is a bit too small, and I would suggest a very low profile focuser to avoid vignetting with low-power wide-field eyepieces.





Mounting

The next major part of the design was to select a mounting configuration. An equatorial mounting for such a large instrument would be massive and expensive and isn't necessary for visual observations of deep-sky objects.

The Dobsonian design is inexpensive and simple, but most such telescopes are relatively heavy and bulky, and they tend to be difficult to point near the zenith. The way they're usually built, Dobsonians don't allow tube rotation for adjusting eyepiece position. I also must admit that I wanted to try something different from the ubiquitous Dobsonian.

Telescopes based on spherical shells in a three-point support base are not new. The popular Edmund Astroscan has been around for years, as have other "bowling ball" mounting arrangements. This "ball in socket" mounting has many advantageous features:

It is very simple because it has only one moving part.

It can be aimed in all directions with equal ease.

It is free of "gimbal lock" near the zenith.

The tube is free to rotate around its own axis for comfortable eyepiece position at any orientation.

The base is a very simple low-profile tripod, which allows for low eyepiece height.

The very low center of gravity (at the center of the sphere) promotes stability.

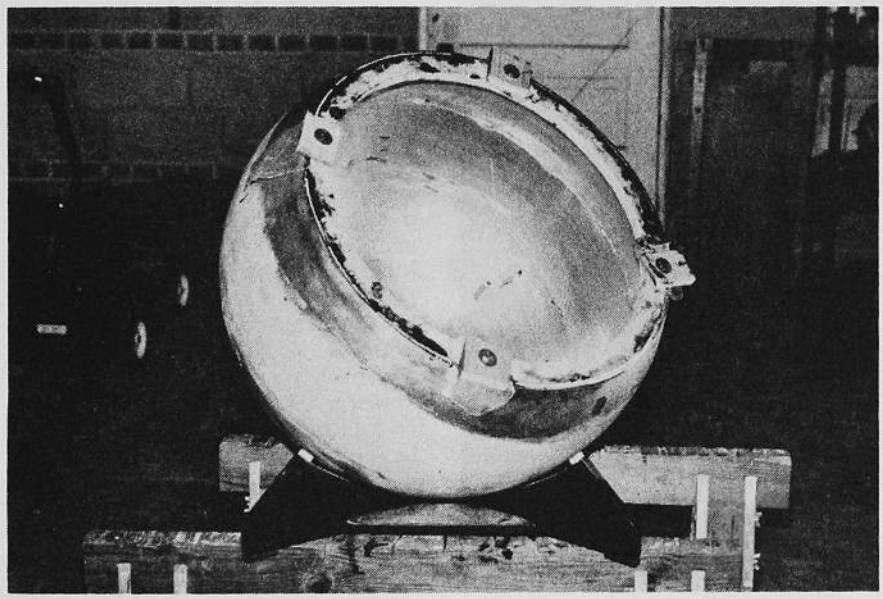
BALANCE ALONG TUBE LENGTH

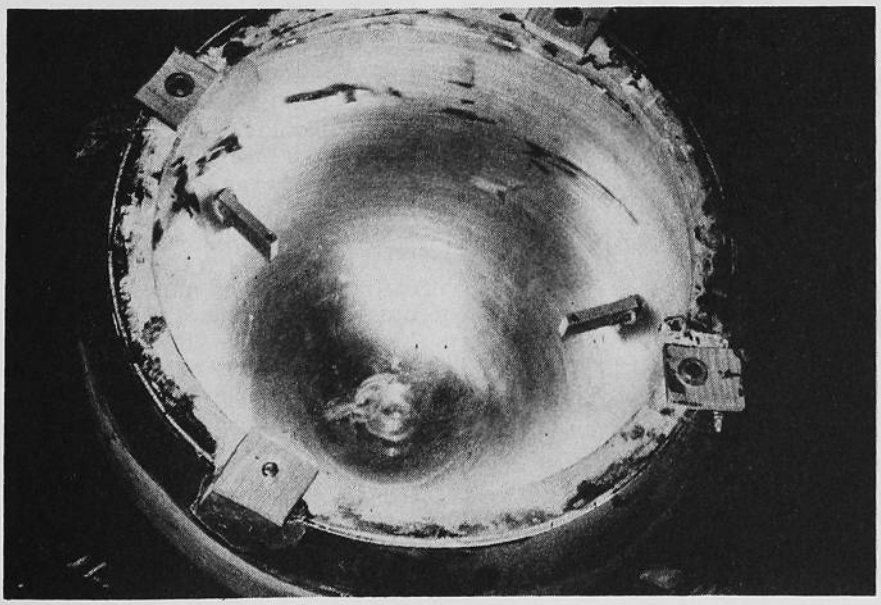
	Weight (lbs.)	Offset (in.)	Moment (in.lbs.)
Primary Mirror	20.5	-7.3	-149.7
Mirror Cell	6.0	-9.0	- 54.0
Sphere	14.5	-5.0	- 72.5
Secondary Mirror	0.5	45.4	22.7
Spider & Holder	0.9	48.0	43.2
Truss Tubes(8)	4.5	23.3	104.9
Upper Tube Asm.	3.5	46.4	162.4
Focusser	0.8	45.4	36.3
7 x 50 Finder	1.5	47.0	70.5
Typical Eyepiece	0.3	45.4	13.6
Subtotal	53.0		+177.6
Counterweight	15.7	- 11.3	-177.6
Total	68.7		0.0*

BALANCE AROUND TUBE AXIS

	Weight (lbs.)	Offset (in.)	Moment (in.lbs.)
Finder	1.5	12.2	18.3
Focusser	0.8	10.2	8.2
Typical Eyepiece	0.3	11.2	3.4
Subtotal			+29.9
Counterweight	15.7	-1.9	-29.9
Total			0.0*

* Zero result here indicates telescope is balanced



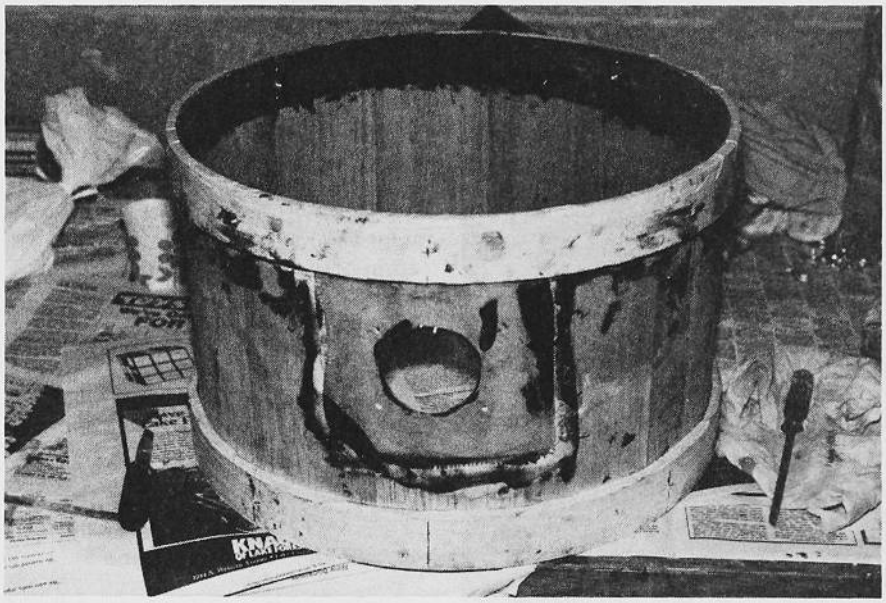


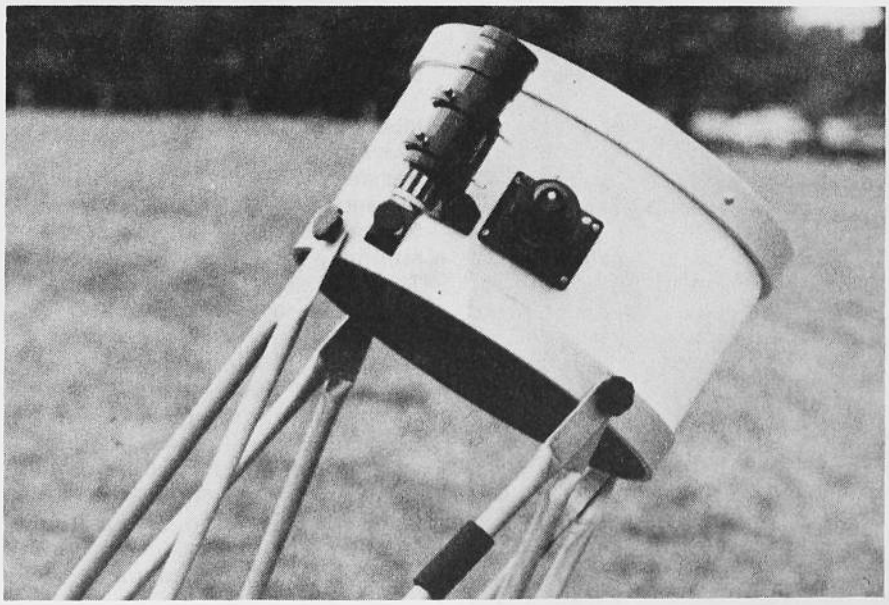
The spherical shell is an excellent structural cornerstone for the rest of the telescope.

You can further enhance the telescope by scaling the design up to that for a large-aperture instrument, incorporating a lightweight truss tube that stores compactly. In fact, if the upper tube assembly is made short enough, it will fit inside the spherical shell and provide an extremely compact storage configuration. A preliminary study of the ball-in-socket concept looked promising, so I decided to complete the design in detail and build a large spherically mounted instrument.

Key Design Considerations

Balance: For perfect balance at all orientations, the center of gravity (CG) must be located at the exact center of the spherical shell. The method for computing the location of the CG for an assemblage of parts is multiplying the weight of each part times its distance from the desired CG, and then adding these. This is summing the torques of the parts. The table shows a list of each part of the telescope, its weight and distance from the center of the sphere, and the product of the weight and distance. If the total torque isn't zero when these are added together, then additional weight must be added to the bottom of the sphere to balance the telescope. This counterweight may be offset from the centerline of the telescope to achieve balance





around the tube axis by the same method.

Finally, I added a small trim weight which is free to slide along one of the truss tubes, to fine-tune the balance of the scope and to compensate for differences in the eyepiece weight. As I studied the design, two very important points soon emerged: 1) the primary mirror must be placed as deep in the sphere as possible to help balance the scope, and 2) every pound of weight in the upper tube assembly (focuser, finder, diagonal spider, etc.) must be counterbalanced by about 4 pounds in the bottom of the sphere. This 4:1 leverage of the upper tube assembly requires that you keep the weight of the upper end to the absolute minimum so the total weight of the instrument doesn't get out of hand.

Mirror Support: The mirror cell presents unique problems. A conventional cell with collimation adjustment knobs on the rear of the cell would be impossible to use since you'd have to drill holes in the sphere to gain access to the knobs. The collimation knobs must therefore extend from the front of the cell (on the same side as the mirror) and must be placed outside the diameter of the mirror. I was able to take advantage of this: the front surfaces of the collimation knobs are used to support the upper tube assembly in the storage configuration.

The entire cell is suspended from three mirror support arms attached to the inside of the sphere. Compression springs are placed

between the mirror support arms and the face of mirror cell so the main mirror can be collimated while sufficient force is maintained against the mirror cell to prevent it from shifting in use.

Storage: Since transportability was an important design goal, I had to devise a compact arrangement for storing and transporting the instrument. I kept the length of the upper tube assembly short so that it would fit inside the spherical shell. This is the key to compact storage.

The first step in stowing the telescope is taking off the finder scope, which is attached with thumbscrews for easy removal. Next I store the finder in an eyepiece case (a standard 5" briefcase I lined with foam). The truss is then dismantled by unscrewing the eight knobs that hold it together and bundling the tubes together with elastic bungee cords. This is an easy operation if the upper four knobs are unscrewed first and the upper tube assembly is removed.

I then place a plastic mirror shield on the collimation knobs over the mirror. The shield is held in place by small adhesive-backed Velcro tabs. The upper tube assembly is then lowered into the spherical shell and a plywood cover placed over the opening. The truss knobs are used to clamp it in place, which also guarantees you won't lose the knobs.

To prevent the upper end from moving inside the sphere, foam pads are glued to the inside of the plywood cover. A band of neoprene weatherstripping is attached to the perimeter of the cover to exclude dust. The 65-pound sphere has two handles that I use to carry it. Although one person can carry it alone, it's more comfortable if you have help.

Construction Details

Base Tripod: The base tripod is a simple plywood unit with three Teflon pads that support the sphere and three urethane feet that rest on the ground. These pads are placed 45 degrees around the bottom of the sphere, which gives good stability while still allowing the telescope to point all the way down to the horizon without the edge of the sphere going beyond the support pad.

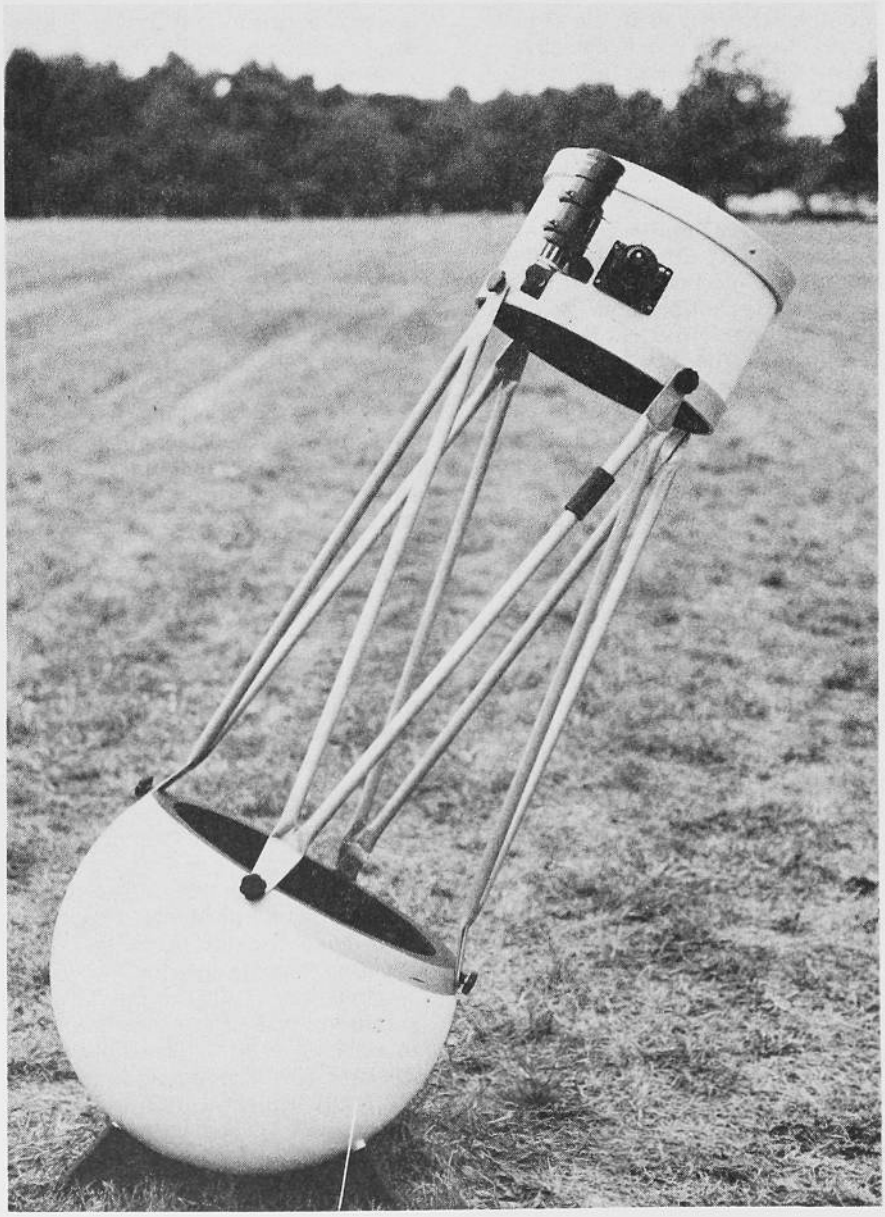
The individual plywood pieces are made from 3/4"-thick 12-ply birch plywood. I cut them with a sabre saw using full-size paper templates glued to the wood with rubber cement. I epoxied the pieces together, making sure that the angle between the legs was 120 degrees. The plywood assembly was then sanded and painted with enamel.

The telescope rests on three small Teflon discs 1/4" thick and 3/4" in diameter. They are attached to the vertices of the tripod with wood screws. Urethane feet made from 90 durometer (very hard) urethane 1/2" thick and 3/4" wide are also attached with wood screws. I selected urethane for the feet because it is extremely abrasion resistant and also has good anti-skid characteristics.

Mirror Cell: The mirror cell is a 9-point flotation cell that provides strain-free support for the relatively thin 14.25" mirror. The cell body is made from 3/4" thick 12-ply birch plywood. I cut it out with a sabre saw using paper templates, and marked the locations for all the holes and inserts with a center punch. I then drilled the holes for the flotation pad pivots and the collimation knob studs and mirror clips. Threaded brass inserts were epoxied in place for the mirror clips and collimation studs, and roundhead screws were epoxied in place for the flotation pivots.

The pivot plates are cut from 1/4" thick steel plate, and holes for the mirror support tips are drilled through. The central holes for the flotation pad pivot point is drilled through, too, and a countersink is used to produce a taper on the rear side of the pad. The flotation pads and mirror cell body are both painted flat black. I used nylon screws as mirror support tips, and they are screwed into the three corner holes in the flotation pads. The flotation pads are attached to the cell body with RTV silicone rubber caulking available at hardware stores. This holds the pads in place but allows them to pivot easily, which provides flotation for the mirror.

Spherical Shell: The most commonly asked question about this telescope is: "Where did you get the big ball?" The sphere is made from 0.10" thick aluminum sheet, which is spun over a wooden hemispherical form. I was able to locate a metal-spinning company



that had a 24" diameter form in its inventory of tools, so the people there were able to fabricate the two hemispheres fairly economically.

To make the sphere, I cut off the top 5" of one of the hemispheres and clamped the donut-shaped piece to the other hemisphere. The two pieces were then welded together. A TIG or Heliarc welder can do the job; a 1" long weld bead every 5" is adequate. I welded the mirror cell support arms to the inside of the sphere. To hold in the proper position, I assembled the mirror cell, set the entire unit in the bottom of the sphere, and welded the arms in place.

A reinforcing ring is necessary at the open end of the shell, not only for stiffness but also for attachment points for the truss. The ring is cut from 3/4" plywood with a 35 degree angle on the perimeter to match the curve of the shell. Four equally space holes are drilled into the face of the ring, and threaded brass inserts are epoxied into the holes. These inserts serve two functions: to fasten the cover to the shell of the finished telescope and to clamp the reinforcing ring to the shell for bonding during fabrication. The reinforcing ring epoxied to the inside of the shell, and clamped in place with four small wooden blocks held in place by machine screws.

The next step is drilling four radial holes into the shell to provide attachment points for the truss tubes. Since these holes enter the sphere at an angle, it is best to use some type of drill guide to help

you drill straight. It is very important to make sure the holes are equally spaced every 90 degrees around the sphere, because the uniformity of this spacing affects the alignment of the truss and hence the collimation of the telescope. Threaded brass inserts are then epoxied into these holes.

The weld seam between hemispheres is filled with polyester auto body putty, and then sanded, primed, and painted with two coats of white epoxy spray enamel. When the paint is dry, wax the entire surface with auto wax: waxing has a dramatic effect in reducing the friction between the sphere and the Teflon pads on the base. This completes the construction of the spherical shell.

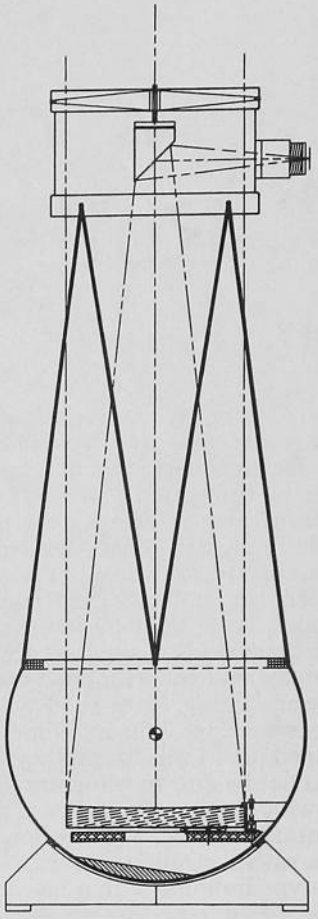
After I completed the telescope I found an alternative source of even better and less-expensive spheres in a variety of sizes: large translucent outdoor lighting globes made from very durable Lexan plastic. Unfortunately, the standard units are too thin to provide adequate stiffness for this application. However, special heavy-wall globes could be made, though the firm requires a volume order and a significant set-up fee. If this design generates enough interest, I may be able to offer kits with the special heavy-wall Lexan globes. This would eliminate the need for spinning and welding as well as eliminating the labor required to finish the seam on the aluminum sphere. The surface of the plastic globes is also smoother than that of the aluminum sphere I made.

Upper Tube Assembly: As I mentioned before, it is very important to keep the weight of the upper tube assembly as low as possible. For this construction I formed a cylinder from 1/8"-thick balsa wood and covered the outside with one layer of very light fiberglass cloth and polyester resin. I epoxied aluminum end rings to the ends of the tube to provide stiffness for the diagonal support spider and for the truss attachment points. The area where the focuser and finder are attached is reinforced with additional fiberglass layers. Finally, the entire assembly is sanded, primed, and painted with white epoxy enamel. The attachment points for the truss tubes use threaded tee-nuts epoxied into the tube and end rings. These must be accurately spaced around the tube for good alignment.

Truss: The eight tubes for the truss are made from 3/4" O.D. aluminum with 1/16" wall thickness. The ends of the tubes must be flattened for a 3" length at each end. This can be done by heating the tubes with a propane torch and then crushing the tube ends in a vise. Heating is necessary so you don't crack the aluminum. The two flat sections at the tube ends do not lie in the same plane but are offset by 45 degrees. The length of the truss tubes must be identical to insure good collimation.

Performance

The finished telescope is very easy to use in the field. Set up time



is five to ten minutes, and the main mirror needs only minor collimation adjustments. The secondary mirror needs very infrequent adjustments.

The unit is extremely easy to point because of its good balance and low friction. It is also easy to aim. Sighting along the edge of the upper tube always brings the target into the finder field. The addition of two LEDs greatly enhances rough aiming. The large aperture is a real step up from the 8" I had before, and the image brightness of deep-sky objects is very noticeably improved.

A complete set of detailed plans and instructions for this design is available for $20. If enough interest is expressed, I could make up some kits that would include the some of the hard-to-find components of this design. Please write if you're interested so that I can begin to work with potential suppliers of plastic spheres.

Thomas P. O'Brien
682 Deepath Dr.
Deefield, IL 60015

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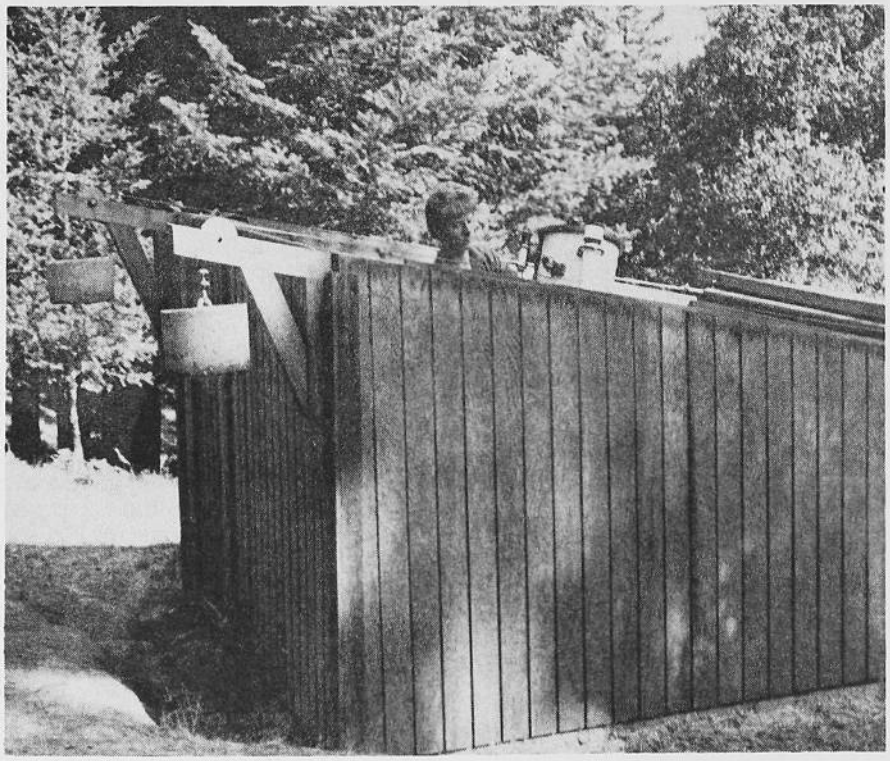
A Counterweighted Roll-Roof Observatory

After reviewing a variety of designs for an observatory to house my newly completed 10-inch Dobsonian telescope, I found none met my requirements. What I needed was an attractive, sturdy, roomy, inexpensive, and relatively easy-to-build structure. Domes were out of the question because they are too expensive and construction is too time-consuming. Most shed-type designs were too homely, flimsy, cramped, and I was afraid they would not be able to withstand the high winds and wet weather of my mountain-top site. My solution was a rather straightforward, shed-type building with a heavy, yet easy-to-move counterweighted roof.

A prime consideration was size: the observatory had to be big enough to work in and sleep in -- but not too big and thus too expensive to build. An 8-foot by 8-foot structure met those requirements. It would have a concrete floor and a redwood-shingled roof.

After selecting and leveling the site, I set up 2x4 forms for the floor. At the center of these I placed a box 20 inches on a side formed of 1x4s. This square would provide a vibration-free pad for the telescope once the concrete around and in it set and the wood was chiseled out. Welded wire was laid in place for reinforcement, and twelve bolts, heads down, were spaces around the perimeter of the forms and would be used to attach the sills.

The south wall, 3 feet high, and the north wall, at 5 feet, were constructed next, with fir 2x4s for sills, studs, and plates. I framed a 20-inch wide opening (to used as a door when the roof was in place) into the north wall. To provide the track for the roof, I set in place two 20-foot long 4x4s extending two feet past the high north wall, and ten feet beyond the low south wall. On the low side the 4x4s were supported by two posts set into concrete. The two side walls were framed in next, and then the whole building was wrapped in felt paper and covered with textured plywood siding.

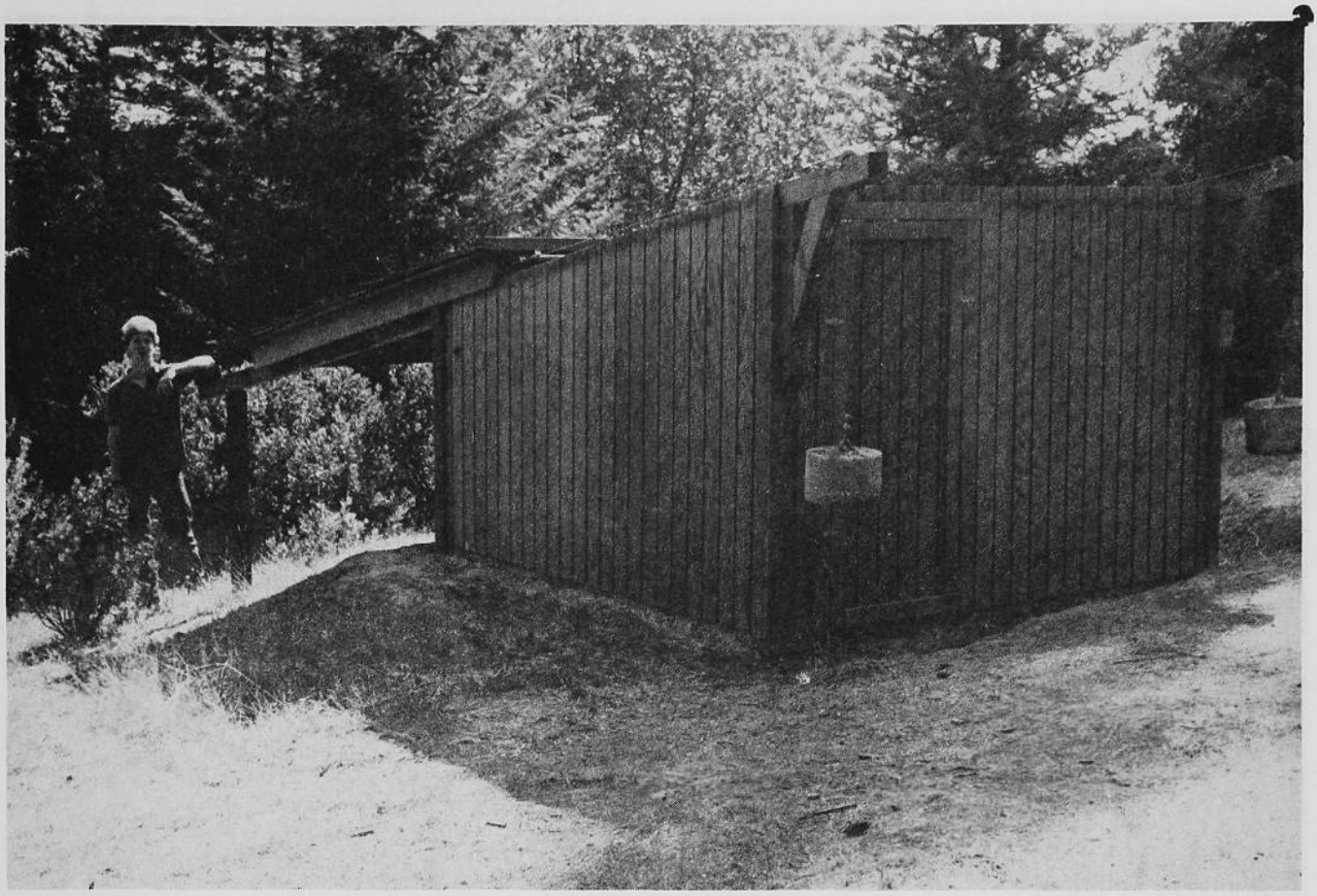


The roof was framed out on the ground. It was constructed of 2x4s on 16-inch centers, with two rows of blocking and corner braces. The roof overhangs each side of the building by 1 inch.

I attached heavy-duty nonswiveling casters to each of the four corners of the roof frame and then lifted the roof into place. After a series of tests for movement and fit, I cut two slots at the top of the 4x4 tracks to allow the top two casters to drop into place. These hold and partially seal the north side of the roof. Strips of 1x1 lumber nailed along the top outside edges of the tracks keep the roof aligned as it moves along the track. Two stop blocks were placed at the low end of the tracks.

After all adjustments were made, the roof was sheathed in half-inch plywood and shingled. On the two sloped walls and the south wall I attached 1x4 skirting to give the building a finished appearance and provide a weather seal for the space between roof and wall. This arrangement was not possible on the north wall because it would have prevented the movement of the roof. Instead, a hinged board, which folds out of the way when the roof is moved, was attached.

At this point the roof was so

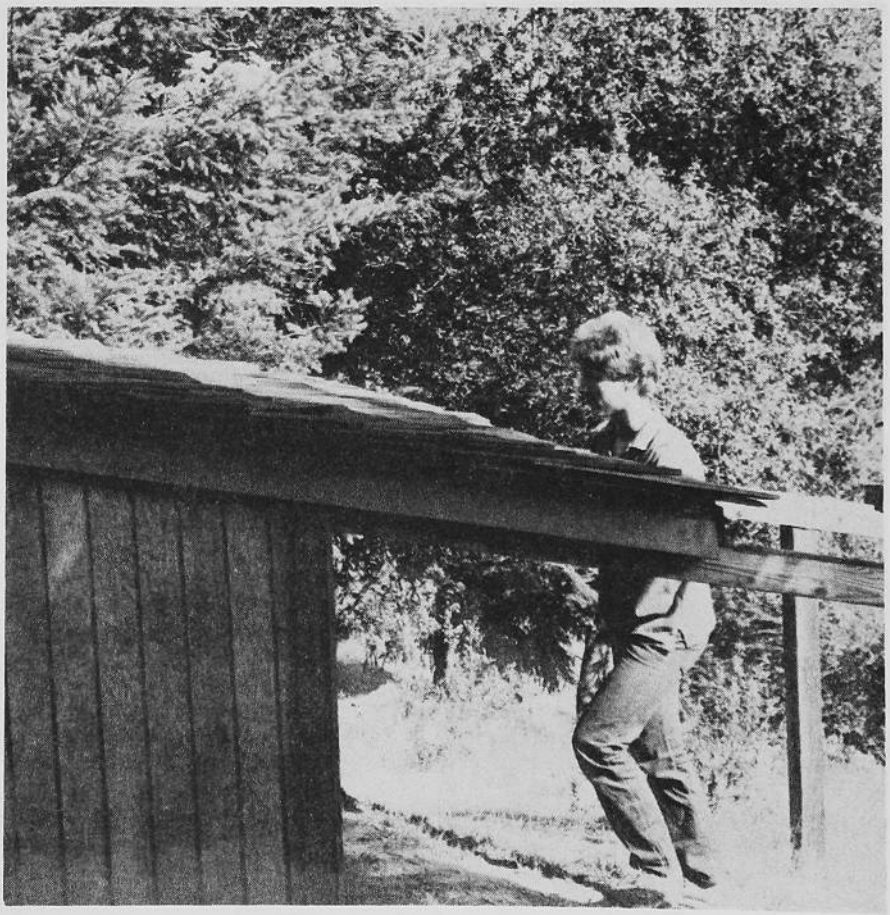


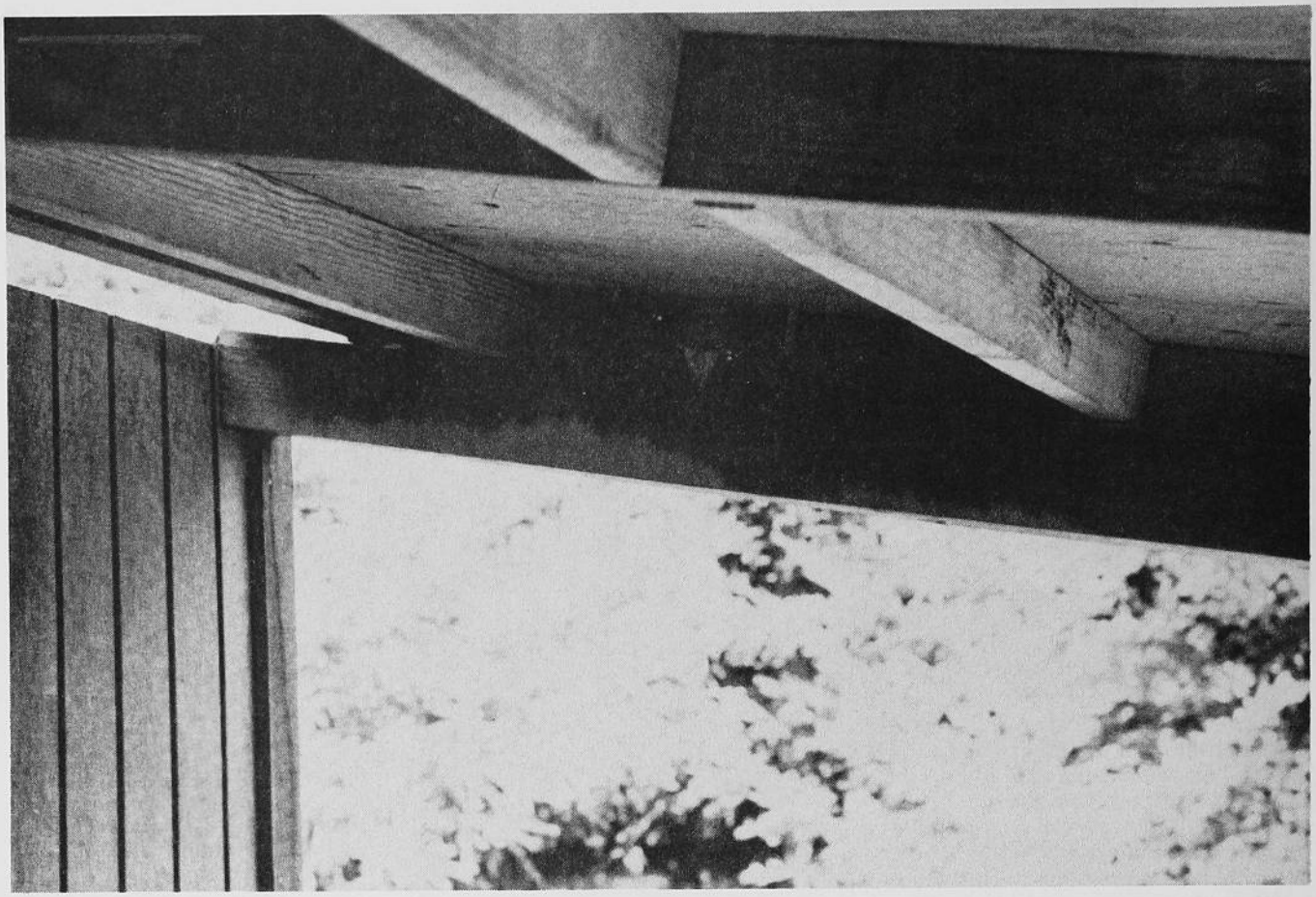
Above: the roof rolled half-way down. Right: the roof rolled all the way down. Note that the counterweights are now fully raised.

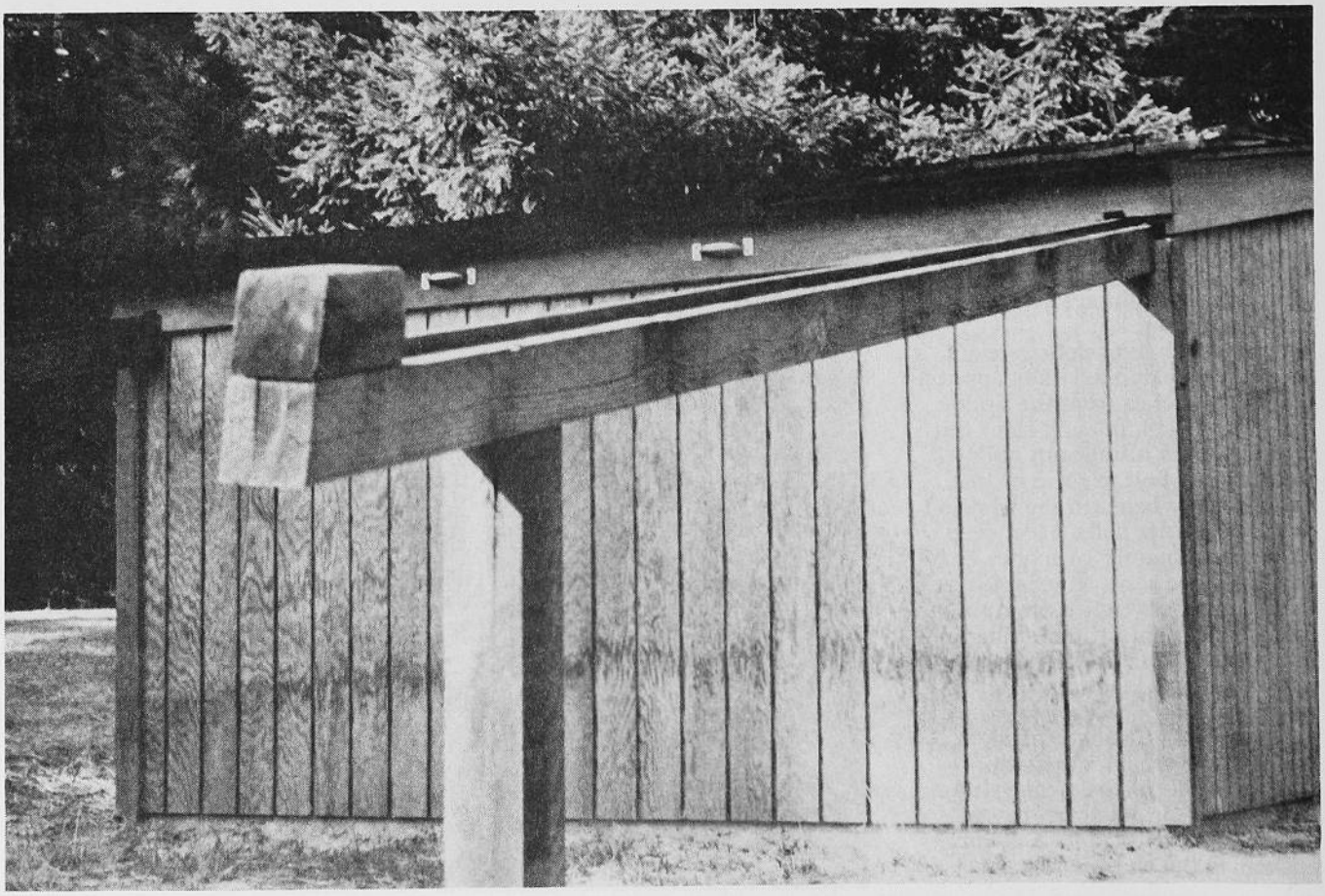
heavy it took two people to move it. Since I planned to open and close the roof by myself on most nights, I had to devise a mechanism that would allow one-person operation. The counterweight system was built as follows:

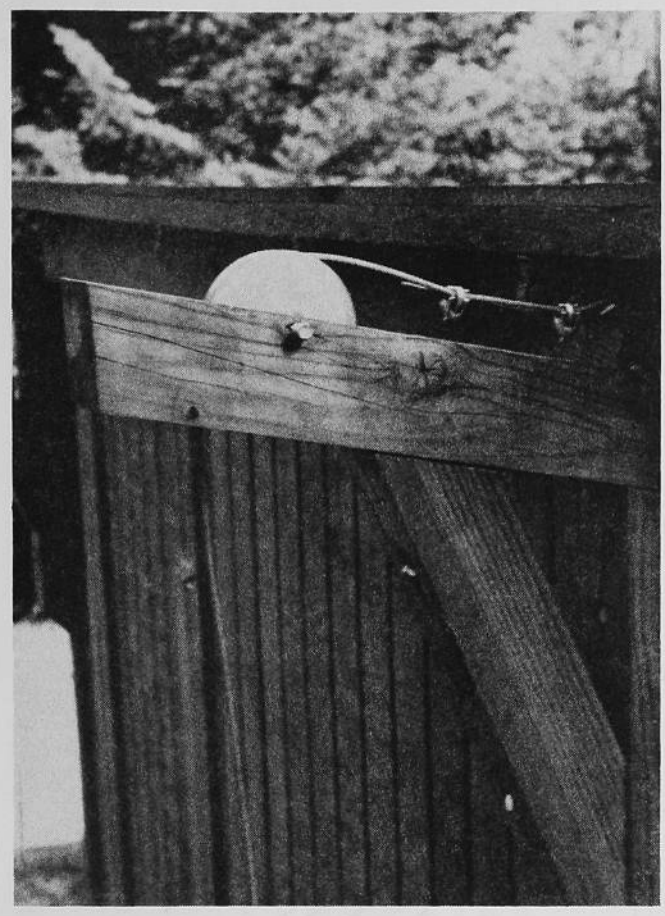
Two 7-inch-long slots were cut through the extended 4x4s approximately 14 inches from the building's north wall. In each slot I centered a 6-inch aluminum pulley wheel with a bolt to serve as its axle. Directly beneath the wheels I dug two circular holes 4 feet deep and approximately 14 inches in diameter; these serve as receptacles for the counterweights when the roof is rolled onto the building. Two 10-foot-long lengths of 3/16" cable were attached to the north side of the roof and draped over the pulley wheels, through the slots, and into the receptacle holes.

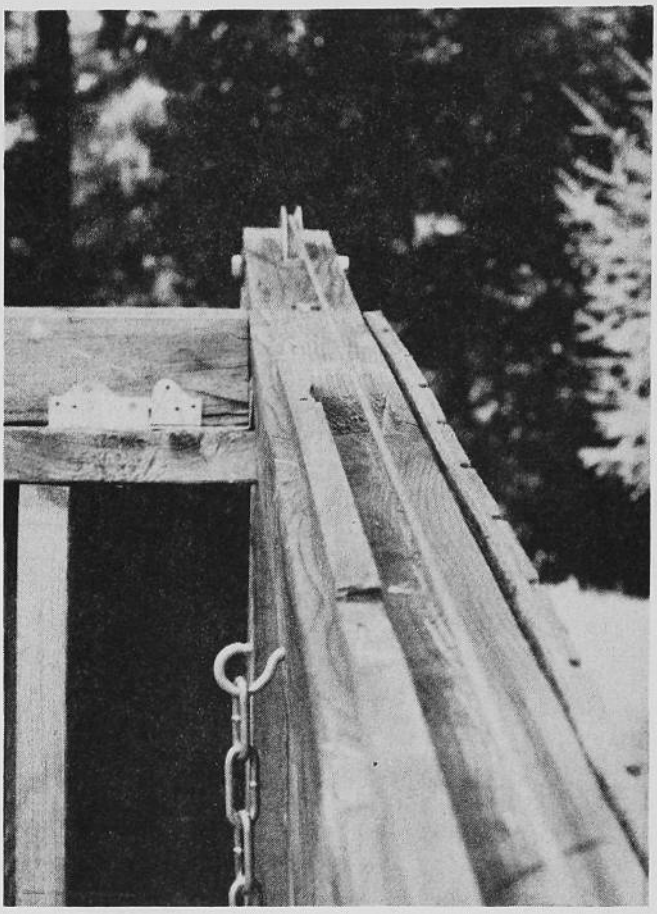
The size of the counterweights was crucial for good roof movement. By attaching two 5-gallon buckets to the ends of the cables



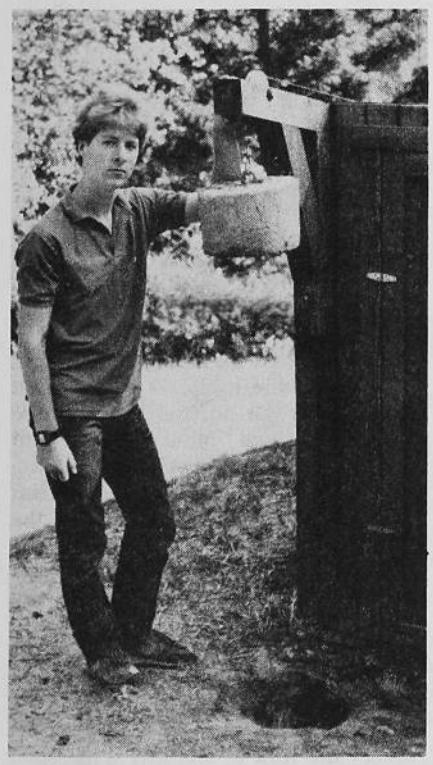








Left: Details of the roof. Above: looking up the track with the roof rolled down. Above right: the counterweight pulley wheel. Below left: the counterweight in its raised position. Note the hole below it. Below right: a concrete pad provides a solid platform for the 10-inch Dobsonian.



and filling them with rocks, I was able to determine the ideal balance point. I then mixed an equal weight of concrete and poured it into the buckets. Each has an eyebolt attached to a wire mesh embedded in the concrete to prevent it from pulling out. After the concrete had cured, I removed the buckets.

I furnished the observatory with a small folding bed and desk, and left the interior walls unpanelled so that the blocking can be used as shelves.

The observatory has proven water- and wind-proof in winter and cool in summer, and the roof moves up and down easily.

Anyone considering building a counterweighted design like this one should note that unless the building is set into a hillside, as mine is, higher walls or a less acute roof angle would be necessary to accommodate the roof track.

I would be happy to respond to queries, but please include a stamped, self-addressed envelope when you write me.

Drew Colfax
Box 246
Boonville, CA 94515

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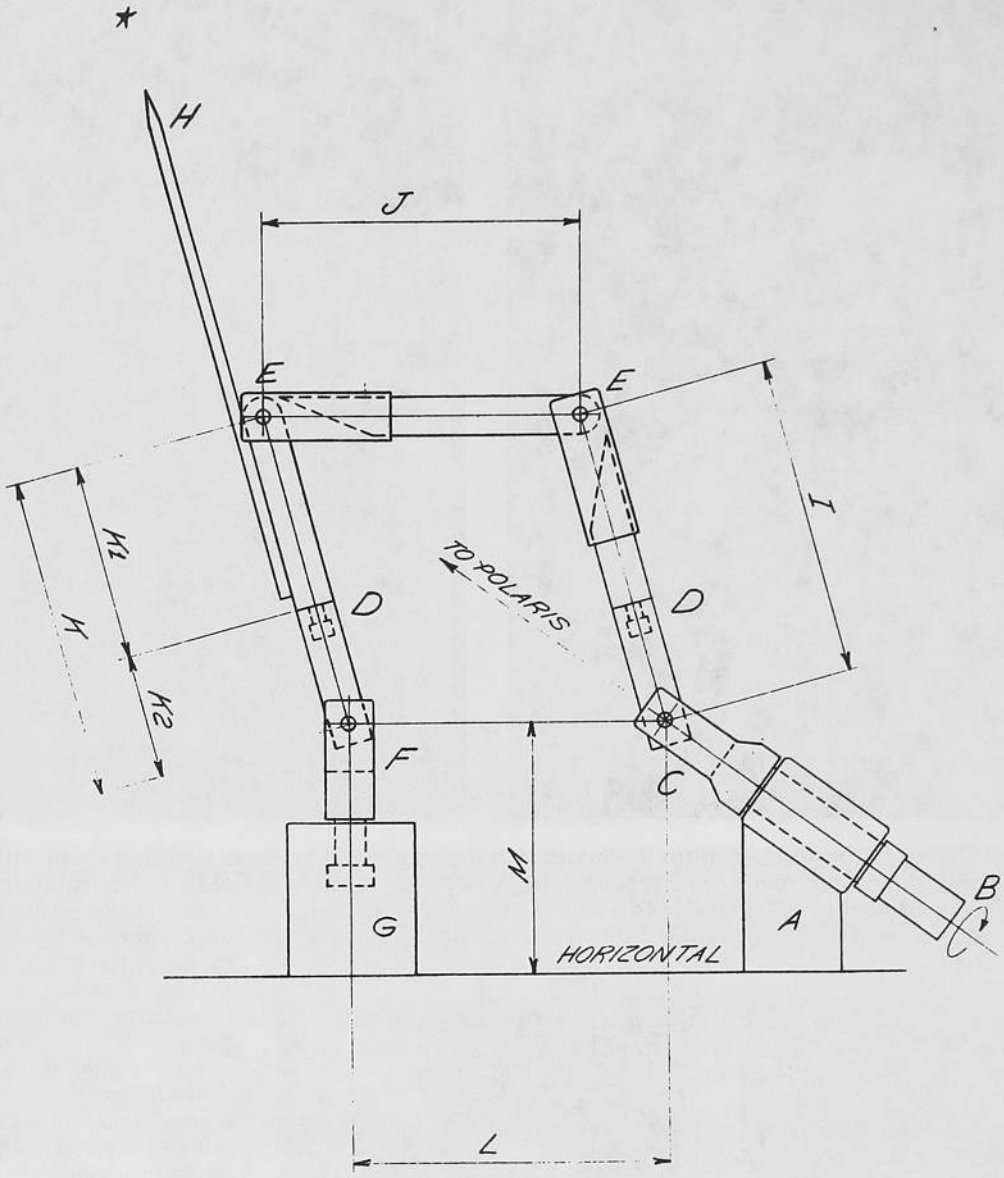

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size of the standard Newtonian. For me or for any individual with the same attitude: give me more theory, give me more math — I can't get enough!

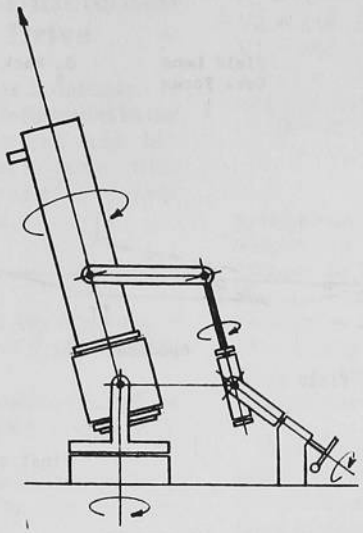
I am writing also to show you an altazimuth drive system that I developed two years ago. It is remarkably similar to the system published in *TM#26* by Mr. Martin Rochette. The sketch describes the system.

Levers I, J, and K are of equal length, and lever J is horizontal. The fork C transmits the torque provided by the drive shaft B to lever I. Fork and shaft C and B are angled at the observer's latitude. Fork F is the telescope's altazimuth mounting. Its horizontal trunnion is at the same height as the trunnion in fork C (the trunnion on Fork C tilts as the mechanism tracks). The trunnions are separated by distance L which is equal to the length of lever J. The pointer H is the axis of the telescope (or is parallel to it). Joint D allows transverse torque relief.

I also built a model of the mount. As you can see, I added a model "celestial sphere" (the half-circle wire) with a moveable "star" and an artificial pole set at my local latitude.

The photographs show the setting-on of the mechanism with the pointer H on a "star" in the northern region of the "sky." Ideally, the mechanism would be clamped at the trunnion in fork C (this is where most of the load in the system is carried). The mechanism, by driving at B, will follow the star in question across the sky as the "night" progresses, and it allows access to all stars above the horizon except those falling in a small "blind" cone around fork C, the size at the cone being determined by the geometry of the system. (I developed equations to allow the figuring of the cone if there is interest.) The mechanism will even track stars under the pole in the northern sky above the horizon.

The long extensions of the levers guiding the instrument force careful attention to tolerances around the trunnions and careful design of the levers and fork C, and this is the chief



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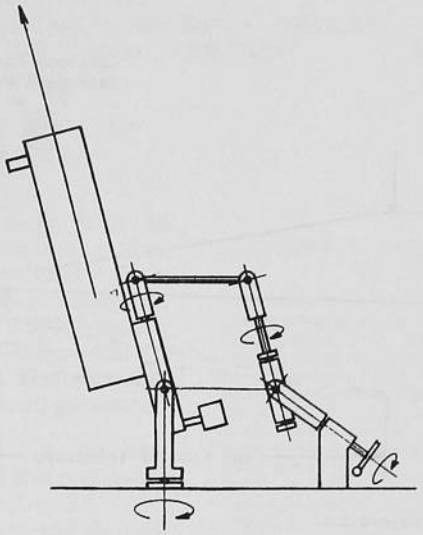

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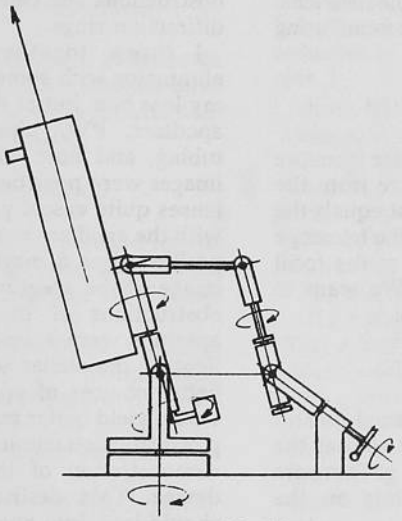

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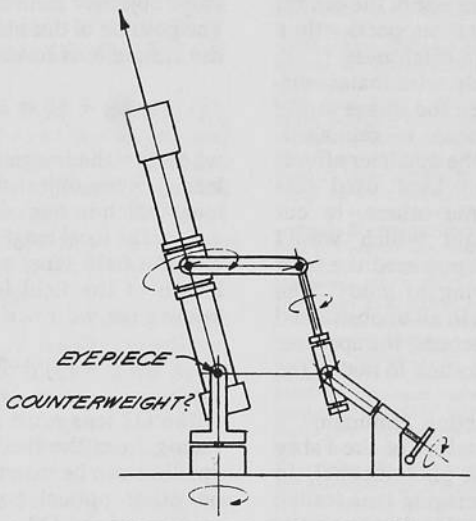


REFRACTOR OR CASSEGRAIN WITH DIAGONAL & SEMIFIXED EYEPIECE

weakness of the mechanism. However, the loads on the system need not be high since the tracking is done so slowly. The field in the eyepiece rotates as in all altazimuth mounted telescopes.

I developed the design after carefully studying the siderostat, which was invented by Foucault.

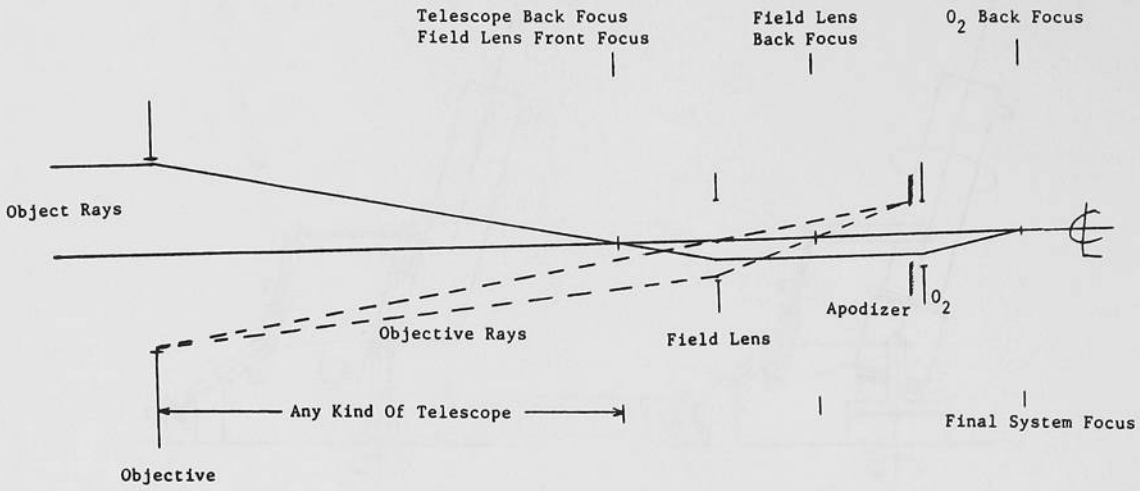
Rick Blakley
1400 B, Clover Street
Winston-Salem, NC 27101

— I believe that a similar device is shown in one of Russel Porter's sketches in one of the Amateur Telescope Making books. Perhaps one of TM*'s readers will build the device for a telescope and send us a description of its operation. (Hint! Hint!)*

Put the Apodizer at the Rear

TM / In *TM#24* I showed that simple window screen apodizers, touted as improving the seeing and resolution of a telescope, actually degrade the telescope's performance. When combined with additional optics, however, an apodizer at the rear end of a telescope can improve the contrast in images, allowing greater perception of fine details than would otherwise be possible. The principles behind this technique have long been known and were first put to astronomical use in 1930 by Bernard Lyot in his newly invented coronagraph. In fact, TMs wanting to improve their view will have to build what is optically a coronagraph back end, which only lacks an occulting disk (unless artificial eclipses are desired). Important work on quasars and nearby possible solar systems has been done using stellar coronagraphs attached to the focus of large telescopes.

Apodize means, from the Greek, "to remove the foot," and in optics that means to remove the diffraction rings outside the Airy disk. As shown in *TM#24*, a "smooth" rather than an abrupt aperture edge will do that. But another method can be used. If a real image of the objective is formed, a specially designed stop — an apodizer — can be used to block out all of the



sharp aperture edges that generate diffraction rings and spikes. This reduces the effective aperture and increases the apparent size of the central obstruction and its supports, thus reducing total image brightness.

It also completely eliminates diffraction effects when the image at the telescope's first focus is reimaged. (Diffraction due to the apodizer affects only images of it.) Lyot used this technique, and some others, to cut down scattered light which would otherwise have overpowered the faint corona he was trying to study. The technique will work in all unobstructed and obstructed telescopes; the apodizer will vary in configuration to match the telescope aperture.

To build a diffraction eliminator, a field lens (the equivalent of the Fabry lens in photoelectric photometers), an apodizer, and a reimaging lens (called the O2, or second objective) are the optical elements necessary. The lenses should be achromatic.

The field lens is placed so that its back focal point coincides with the telescope's focal point, just as an eyepiece's would. For objects no more extended than the planets, the lens doesn't need to be much larger than that necessary to match the f/ ratio of the telescope. If it is oversized, the diffraction eliminator can be used with no loss of light from the outer zones of faster telescope objectives or on more extended objects like the Moon.

After passing through the field lens the object's rays are now parallel and will eventually enter the O2 for final imaging. The O2 can match the field lens to make a unity-power system, or it can act as an amplifier if desired. This final focus can be used just like the normal focus of a telescope, with a camera back or eyepiece complete the viewing system.

The key to eliminating diffraction effects is masking the image of the telescope objective formed by the field lens. The position of this image is found using the simple lens formula

$$1/g + 1/j = 1/F \qquad (1)$$

where g = the image distance from the lens, j = the object distance from the lens, which in our case just equals the sum of the focal lengths of the telescope and the field lens, and F = the focal length of the field lens. We want to know g, so we rewrite (1):

$$g = F \times j/(j-F) \qquad (2)$$

The O2 lens must be placed greater than g from the field lens so that the apodizer can be inserted at g. There are no other optical constraints on the position of the O2.

The heart of the system is the apodizer. Its sharp edges should obscure all the sharp edges at the entrance aperture. In practice this means that the clear aperture of the apodizer should be slightly smaller than the image of the objective aperture (which is found using this equation):

$$i = g \times A/j \qquad (3)$$

where A is the diameter of the objective aperture. Any secondary should be obscured by a slightly oversize counterpart on the apodizer (substitute the secondary diameter for A in equation (3) to get its image size). Any secondary supports should also be obscured, but in this case the apodizer counterparts will be much larger than the images of the supports purely for mechanical (apodizer construction) reasons.

The fully assembled system should improve the image contrast. The result will be especially noticeable on instruments with large secondary obstructions and concommitant bright diffraction rings.

I threw together a diffraction eliminator with some achromats from my lens box, butter dish plastic for an apodizer, PVC pipe fittings, 1.25" tubing, and hose clamps. While the images were poor because I chose the lenses quite casually, I could see that with the apodizer removed and the O2 positioned as a magnifier of the real image of the aperture, the edges and obstructions of my C-8's entrance aperture were aglow from diffracted light of the stellar source. Obviously better choices of optics and material would yield better results but my junk pile diffraction eliminator gave a useful demonstration of the power of the device. TMs desiring a good view should look into one.

Some of the research described in this paper was carried out the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.

Stephen J. Edberg
Jet Propulsion Laboratory
California Institute of Technology
4800 Oak Grove Drive
Pasadena, CA 91109

— While I see how the reimaging system could eliminate some diffracted and scattered light from a bright star that's been occulted, I'm skeptical that one can so easily "completely eliminate diffraction effects." I'll bet that the point spread function of a star not blocked by a mask shows, at the focus of the reimagining system, a diffraction pattern characteristic of the second mask. Those li'l photons are sneaky types and they always know where they've been.

Computing the Differential Hypocycloidal Drive

Dear Mr. Berry / This is intended to shed a little light on the formulas in the article by Mr. Haasteren and Mr. Simons in *TM#26*, and to demonstrate what happens when different parameters are varied.

Given:

- rA, rB, rC, and rD are the radii of rings A and D and of discs B and C;
- n1 and n2 are the rotation rates of the input and output shafts, respectively;
- V1 and V2 are the velocities of input and output shafts, in surface-inches/minute.

Then:

$$V1 = \pi \times d1 \times n1$$
$$V2 = \pi \times d1 \times n1 \times (rC - rB/rB)$$

where d1 is the difference in diameter between rings and discs, and the term in parentheses is the ratio of reduction.

V2 is also found from:

$$V2 = 2 \times \pi \times rD \times n2$$

where rD is the radius selected for the output ring or shaft. n2 should be 1/1436 rpm = 0.000069637 rpm for sidereal rate telescope drives.

Note that (rC−rB/rB) is the total reduction, the single step mentioned in the *TM#26* article. Discs B and C must be connected so that they rotate at the same rate. If this is the case, then:

$$V1/V2 \# (n2 \times rD/n1 \times C) = (rC - rB/rB)$$

and therefore:

$$n1 = n2/(d1 \times (rC - rB)/(2 \times rd \times rB)$$

Do not use rounded-off figures when evaluating these equations. The different formulae are useful when using different approaches. Select those parameters best suited to your needs and then calculate the others.

For example, suppose you have a synchronous motor drive with an output of 1 rpm, and you want your reducer to be no more than 5.5″ in diameter. Let ring D be 5″ diameter. Thus, n1 = 1rpm, di = 0.03125 inches, n2 = 1/1436 = 0.00069637rpm, and e = d1/2 = 0.015625 inches. The bar means a parameter is the selected parameter.

rC = rD−e = 2.5−0.15625 = 2.4844
V2 = 2×π×rD×n2 = 6.28318×2.5×.000069637 = .098174687
V1 = π×d1×ni = 3.14159×0.03125×1 = .098174687
V2/V1 = .1114192 = rC−rB/rB
and therefore:
rB = rC/(1+0.1114192) = 2.2353
rA = rB + e = 2.2369

This completes line 1 in the table below. Now double rD and recalculate everything except d1, n2, and n1. n2 is fixed for telescope drives, and we want to leave d1 and n1 the same. This gives line 2 in the table. Now double d1, leaving rd at 5″. This gives line 3 in table. Now double n1, leaving rd and d1 the same, for line 4 of the table. Remember that V2/V1 is the ratio of reduction in velocity (rC−rB/rB) and not rpm.

Note that the input velocity, V1, changes when d1 or n1 is changed, and V2 changes when rd is changed providing n2 remains fixed. By varying either of these parameters, the V2/V1 ratio may be calculated to obtain any desired input RPM. Set n1 to desired RPM and calculate.

The authors show a dust seal between Ring A and Ring D. An O-ring will do, since there is no great speed here. Apply light grease at the time of assembly, install shielded bearings on each input shaft end, and the unit will work nicely. The center bearing on the eccentric should be a double row self-aligning bearing, as shown.

By the way, I'm sending this in response to "Ain't Much I'm Askin' " (Letters, *TM#26*) where you asked readers to write about the sorts of things we'd like to see in *TM*. Your reply encouraged me to do just that.

Theodore Schulze
8 Redbo Lane
Asheville, NC 28806

— *Thanks for the vote of confidence.*

Line	V1	V2	$\overline{n_1}$	$\overline{rD}$	rC	rB	rA	$\overline{d_1}$	e
1	.098174687	.000938545	1	2.5"	2.4844	2.2353	2.2369	.03125	.015625
2	.098174687	.02187709	1	5"	4.9844	4.4761	4.4917	.03125	.015625
3	.196349375	.02187709	1	5"	4.9688	4.4706	4.5019	.0625	.03125
4	.392698375	.02187709	2	5"	4.9688	4.7066	4.7378	.0625	.03125

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Changing the Aperture Pupil

Introduction

Recently there has been a lot of interest in apodization, a grandiose name for a simple process. "Apod" means "without feet" and is the process of modifying the tranmission of the aperture to lessen diffraction rings. I personally prefer the terminology of sonar and antenna-design folks, who refer to this process as "shading."

More mythology has grown up around apodization than in almost any other topic in telescope making. You'll find "apodization True Believers" and "apodization atheists" and everything in between. The long-running brouhaha about apodization in the pages of TM is a good example of this controversy. In case you are curious about where I stand, I am one of those people in between. I think that apodization gives the telescope user yet another tool, in some situations, to get an improved image. But I believe that misuse and incorrect information passed by word of mouth have gotten in the way of their proper application.

My first contact with apodizing screens illustrates this. I met a couple of telescope makers at the Apollo Rendezvous who had this peculiar screen with holes in it, so I asked one of them about it. He told me wondrous tales of how it improved the image immediately after putting it on. I took a closer look at the screen. It was made of plastic onion/potato/apple sacking material with a transmission of at least 90% and a cell size of over 1/4 inch. It covered everything beyond about 50% to 70% of the aperture and was made as a one layer screen. I hope to instruct readers of this article well enough for them to realize that this screen would have been worthless as an apodizer and possibly actively harmful, as the garbage spectra on either side of the image were only diverted 18 arcseconds and would disturb a large planetary image.

But the guy who owned that screen looked in the eyepiece and believed he saw a better image -- and that reveals to us the primary characteristic of improvements obtained through apodization: they are extremely subtle. If an apodization screen results in too significant a change, then it is probably accidently curing a problem for which it was not designed, a problem which could probably be cured by simply stopping down or darkening the image.

Apodization is far up on the curve describing the quest for perfection and is effective only when an instrument already approaches perfection. Apodization is a fanatic's move, similar to the sometimes irrational behavior of people who own expensive high fidelity equipment. If you don't own impeccable optics, I don't expect apodization to help much -- unless the screen covers the telescope's optical problem.

I am not standing as a judge. The plan with this article is to develop techniques and tools to allow readers to intelligently design and construct their own apodizing filters. They then can judge for themselves. Nevertheless, I reserve the right to express my own opinions.

And if, after reading this article, you find you're fascinated by apodization and want to learn more about the way these calculations were done, see if a local college or university has a beginning engineering department course on signal processing, or, better yet, optical signal processing. Analog signal processing is what we are doing when we put an apodization screen on our telescope.

What Is Diffraction?

A brief description of what it is we're trying to get rid of is necessary, I believe, to understand apodization. Everyone knows what diffraction rings are: they're those little rings that seem to surround stars. They are difficult to observe in large telescopes and easy in small ones. Some people regard them more of a badge of honor, a statement of optical quality -- rather than a source of trouble -- because they are seen only when pretty fair optics and conditions exist. Rings are not "noise" in the classical definition -- incoherent backgrounds from indeterminate sources -- but they nonetheless interfere with the production of a good image.

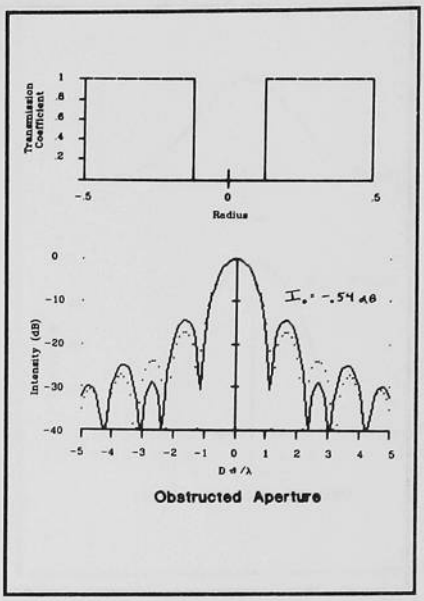
Few TMs know what causes diffraction rings, and most think of them as unavoidable, something that comes with the territory. To understand them we must introduce the concept of a Fresnel (pronounced Fray-nel') zone. Imagine that you are sitting on the axis of a perfect optical system; the incoming wave would be perceived by you to originate everywhere on the aperture, and in phase (phase is the most important factor). It would be said of you that you could detect only one Fresnel zone on the aperture. Your position is awash in light.

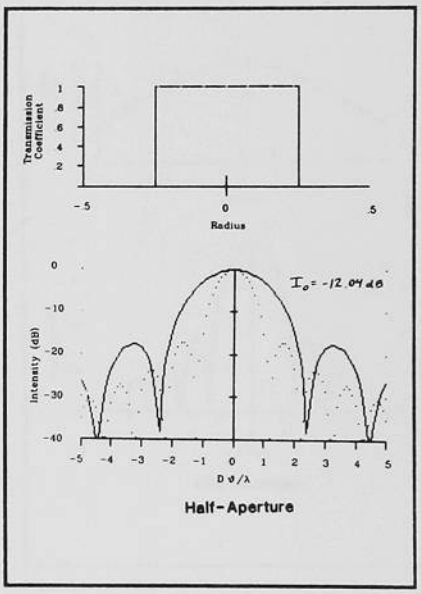
Now say you wander sideways until the aperture is slightly tilted with respect to you (I'm not talking about much tilt here -- maybe a wavelength). The light still originates at the aperture in phase, but the portion of the wave starting out from the more distant part of the aperture must travel farther than light from the near side of the aperture to get to your cockeyed position. It thus arrives out of phase.

Those parts of the aperture with a wave going positive at a certain time we designate as positive Fresnel zones; those parts of the aperture with the wave going negative at the same time we designate as negative Fresnel zones. When you get to the angle where the area of the negative Fresnel zones are equal to the positive, you see no light because the zones exactly cancel. You are at the angle of the first minimum of the diffraction pattern.

If you continue moving off axis, you come to a place where you see about three Fresnel zones on the aperture. One positive zone approximately cancels the negative zone, and the remaining zone provides a net (though smaller) response. This is the first diffraction ring. The second mimimum comes when there are four Fresnel zones and the positive and negative areas once again cancel. This description is flawed in that we have a circular aperture and a sinusoidal oscillation in the phase of the zones, but the problem, when worked out fully, is approximately described by by the above.

It is possible to understand from the Fresnel zone description how the aperture is tied integrally into diffraction. We had to define an aperture before we knew what Fresnel zones contributed. The Fresnel zones exist in the plane of the aperture, independently of the aperture.



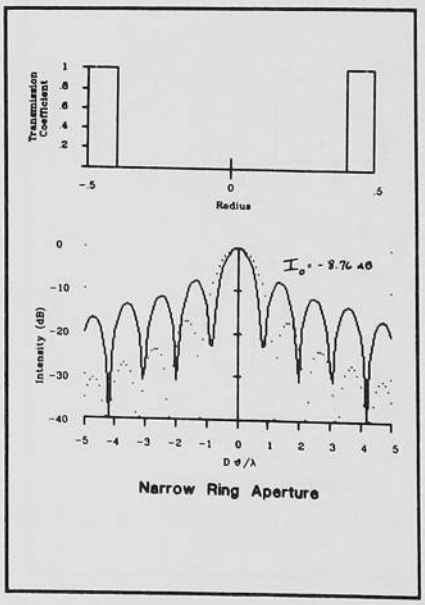


What is Apodization?

The above Fresnel zone description has the implicit assumption in it that all points on the aperture contribute equally. What if we try to "conceal" the fact that we have a certain aperture by smoothing down the corners of our window by changing the transmission coefficient? Does the resulting smoothed aperture fail to have diffraction rings because it can't find angles at which the Fresnel zones cancel? Using avery specific functional form, the Gaussian, it turns out that it does.

The Gaussian pupil shape has very nice properties, among them the capability of Fourier-transforming into another Gaussian. Although the Fourier transform (FT) is much too complicated for a discussion here, let me just note that when you perform a FT on an aperture (or "pupil function") what you get back is a "response function" that, when squared, is proportional to the intensity of the emerging wavefront as it changes with angle. If the pupil function is a Gaussian, then the response function is Gaussian, too. There are no diffraction rings. Naturally, the Gaussian function must be truncated somewhere, but its width can be chosen to be as narrow as you might desire, and therefore truncate the Gaussian at any value.

Thus you can, to abitrarily high precision, suppress diffraction rings. But looking at the results (see the figure labeled "Strong Gaussian") leads



one to the conclusion that the cure is worse than the disease. To reduce the side rings below the level -40dB, we must pay a terrible price in resolution. Surely there is some compromise that will allow us an improved image without undue loss of resolution. It is the purpose of this article to give readers a tool to use for experimenting with mild apodizers until they have a good intermdiate filter.

Where Is The Aperture?

This seems like a silly question, but it isn't. The aperture, for our purposes, is anywhere the light from a point source is moving parallel (or is "afocal"). For a simple telescope pointed at infinity, this is anywhere in front of the objective (although in reflectors it is necessary to place the filter in front of the secondary to avoid two passes) or it is clear back at the exit pupil of the eyepiece. The magnifications for which we want to use apodization are high ones with small exit pupils. Since making a gradually changing filter for a less than 1 millimeter exit pupil would be extremely difficult, however, and you can't change eyepieces without having to change apodization filters, most people opt for a full-diameter apodizer.

Earlier Work

Apodizing for amateurs started with a letter to The Amateur Astronomer column of Scientific American in May 1951 by E. E. Webb. Webb suggested that secondary diffraction could be eliminated by rounding off the transmission at the edge of the secondary. This idea was discredited in the August 1951 issue by an analysis originating with John Strong, but it led to further thinking about the subject of modifying the pupil function by amateurs.

One reference describing one of the earliest amateur attempts to actually do something about the pupil function was given by Arthur Leonard in the June 1954 issue of Scientific American. In this article, Mr. Leonard mentions an apodizer made of ordinary window screen. Similar screens will be described below.

On the professional side, Jacquinot and Couder (of Couder mask fame) made a one-dimensional apodizer in the late thirties in the shape of a diamond to suppress "echo" lines created by the slit of a spectrograph.

The process of doing apodization calculations has a long past. In the forties, a theorist named Luneburg published a treatise on optics in which he mentioned an apodization calculation. His conclusion was that resolution could not really improved by this method, but that contrast could be manipulated quite a lot.

The title of world's most persistent apodizer goes to a gentleman named J. Ernest Wilkins Jr., who published papers about the topic in 1949 and 1984, with plenty in-between, giving him a time spread of 35 years (although I'll admit Arthur Leonard isn't far behind).

The most concentrated and useful information about the topic appears in a gigantic review article by Jacquinot and Roizen-Dossier in 1964, where they review apodizers based on theory and some apodizers based only on speculation.

All of the above references and some besides are contained in the "Apodization Bibliography" at the end of this article.

The Program APODIZE

I have written an apodization calculation routine with many transmission behaviors built in. The menu for transmission coefficients offers the following choices: a uniform aperture, a 4-layer stepped screen, a Gaussian, a Fermi distribution, the Gaussian starting at a certain fraction of the aperture, and a four-term polynomial function of the form (1-4*r^2)^N, with N varying from 0 to 3. It takes either of these pupil functions or an inverted form of them. Anyone who wants to add any other way of defining transmission coefficients must add it to the menu at the front and the transmission coefficient subroutine at the back -- but see my note at the end of this section.

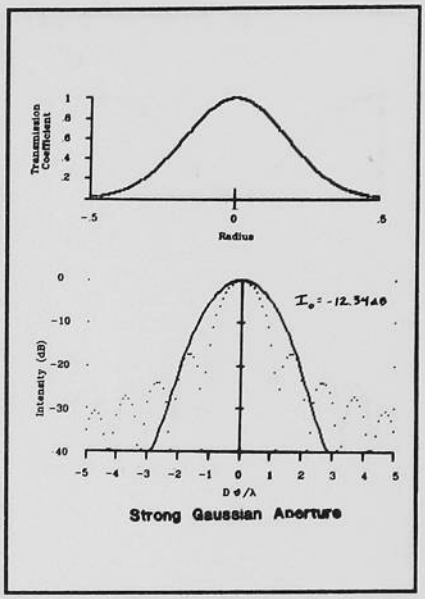
The program takes inputs in units of the radius of the aperture (i.e., values up to 0.5). It also takes a wave amount of defocusing and spherical aberration, and the radius of central obstruction. Not all of these are meant to be invoked at the same time, but I put defocusing and spherical aberration

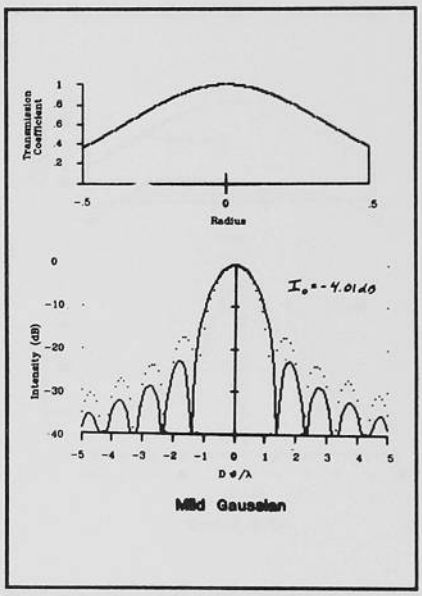
in the form of the orthogonal Zernike circle polynomials so they will work together. (See Born & Wolf, Principles of Optics, 6th. edition 1980, Pergamon Press, the chapter on the diffraction theory of aberrations. The circle polynomials you find there are in a slightly different form; the radius varies from 0 to 1.0 rather than 0 to 0.5).

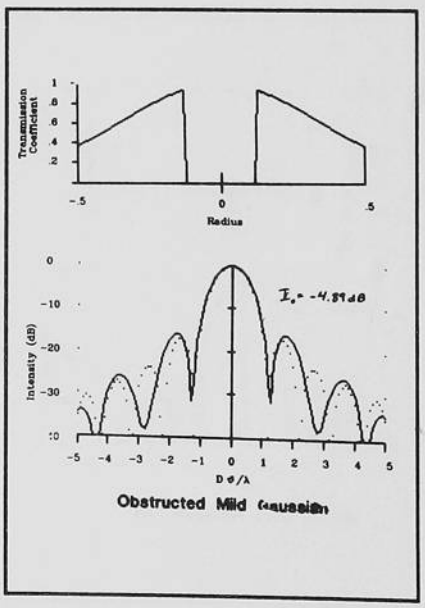
The program is useful for other types of calculations besides apodization. You can see the effects of pure spherical aberration as well as central obstruction. Defocusing is mathematically similar to moving in from the Fraunhofer distance to Fresnel distances, so you can find the diffraction pattern of your favorite pinhole camera by merely calculating its sagitta in wavelengths and inserting that for the number of wavelengths of defocusing. The program normalizes to the on-axis intensity, so you should expect peculiar results when defocusing is strong enough to result in an on-axis minimum.

The program is written for an IBM-PC or PC-compatible using Basica 2 or beyond. The program is slow (10 to 15 minutes when using a large number of sources) in compiled (QuickBasic 1.0, by Microsoft) form, so it executes glacially using the original interpreter. To be frank, I have never executed a non-compiled version, so I don't know how long it takes to crunch (or should I say, to gum) all of those numbers. I'd estimate a few hours. My advice to you is just to start it and walk off. Unwatched, the pot soon boils. The program beeps when it needs help.

If you mess with this program, be sure to make clear, in anything you write or publish, that your calculation was done with a modified version of my APODIZE program.







What The Program Does

APODIZE first shows the points selected for the aperture and then the transmission function and aberration chosen. It does this so you can plot them out if desired. Also, this serves as confirmation that you are calculating what you think you are. It then performs the calculation of the diffraction pattern. This pattern is calculated in dimensionless units so you don't have to put in the focal ratio and diameter. For comparison with the function being coputed, the program also displays the pattern for an unobstructed circular aperture by drawing it with dots. Note where the first minimum in the dotted diffraction pattern -- at the value D*Theta/Lambda = 1.22 -- corresponding to the Rayleigh limit for resolution.

The program models the surface as a set of Huygens-Fresnel sources, with the effect of transmission, obstruction, and aberration applied to each of them according to their radial distance. It takes advantage of a symmetry in that it only calculates points residing in one half of the pupil with the division into halves taking place along the line of tilt. It doesn't calculate the discrete Fourier transform per se, with as many frequency components as position components, but instead adds up the effect of all the wavelet sources for a given tilt angle in units of wavelengths. It splits up real and imaginary parts of the exponential and acts equally on them with the transmission coefficient. Thus, imaginary (or phase-shifted) transmission coefficients are not allowed, but negative transmission coefficients are possible. All results are scaled to 0 dB on axis with the on-axis intensity, Io, written out. As with all discrete approximations, expect high accuracy only when the number of points chosen is large. This is particularly true for calculations of the High Ring Screen described below.

The last thing the program does is calculate and display the optical transfer function (OTF), an expression describing the system's ability to transfer contrast between incoherent sources, plotted against spatial frequency. Everyone has seen one of those Air Force resolution charts with little black and white bar patterns getting smaller and smaller at various orientations; the OTF describes the contrast of those patterns in the image formed by the optical system unders tudy, with the exception that the pattern the OTF deals with is a sinusoidally varying one, instead of the square wave of a bar pattern.

The particular frequency transfer function I've chosen, the OTF, has the capability of going negative. What this means is that it still delivers contrast, but that contrast is reversed -- light looks dark and dark looks light. (I'm not kidding, this has been really been observed to happen at certain spatial frequencies in the presence of aberrations. It frequently happens with defocusing.)

The absolute value of the OTF is called the modulation transfer function.

Because of the small number of points (less than 1000) used to approximate the integral, don't expect great precision from this part of the program either. OTF is plotted from a spatial frequency of 0 to a spatial frequency Smax representative of the resolution:

Smax = 1/F*y

where the units are cycles/unit length in image plane, F is the focal ratio, and y isthe wavelength.

For example, Smax for a f/10 optical system is 181.8 cycles/millimeter, assuming light of wavelength 550 nanometers. For an extremely lucid discussion of transfer functions and what they indicate, see the article by M.A.M. van Venrooij in TM#16. You can check your typed-in version of the program by reproducing the transfer function for an unobstructed aperture with 1/4 wave of spherical aberration -- it checked out on mine.

An sample execution would go like this, with user inputs in square brackets:

```
APODIZE program  by Dick Suiter
Approximate number of points across aperture (odd<50)? [49]
Maximum defocusing aberration? (waves) [0]
Amount of spherical aberration? (waves) [0]

Choices for apodization:
1) T = 1
2) Four-zoned screen: T=t1 (r<r1); T=t2 (r1<r<r2)
                      T=t3 (r2<r<r3); T=t4 (r3<r<.5)
3) Gaussian: T = exp(-4*r^2/n^2)
4) Fermi: T = 1/(1+exp((r-R)/a)
5) Gaussian start at r0
6) Polynomial coefficients of terms like (1-4*r^2)^power

Make choice-> [2]

Inner transmission [1]
Out to radius [.20]
Inner-middle transmission [.66]
What is r2 radius? [.30]
Outer-middle transmission [.44]
What is r3 radius? [.36]
Outer transmission [.29]

Central obstruction radius? (r < .5) [.125]
Inverted transmission? (T = 1-T) [n]
Scaling needed? [n]
Message? [Obstructed Apodizer]
```

The translation goes like this: the number of points across the aperture is selected to be near the maximum because we want the calculation to be very accurate. We don't want defocusing and spherical aberration, so we set them to zero. We choose the step screen to be the functional form of the transmission. We want an aperture of the following form: 40% of the aperture open, one layer of screen (T=.66) starting at 40% and continuing to 60% of the aperture, two layers of screen (T=.44) between 60% and 72% of the aperture, and three layers (T=.29) beyond that.

The obstruction ratio is 25%, which means that the obstruction radius is .125 of the aperture. We want the transmission just like it is, so no inversion of the transmission is required. The maximum transmission is 1 so no rescaling is required. The message that we will have printed on a couple of graphics screens is "Obstructed Apodizer."

You will note if you execute the program with these parameters that it results in only a 1.5 dB drop in the height of the first ring. From this you might conclude that it is a poor apodizer. I ask you to judge this filter a little less harshly. Remember that we started not with the unobstructed aperture, but with an aperture having a 25% obstruction ratio, so the first ring was brighter than that of the comparison curve (see the figure showing an Obstructed Aperture).

Naturally, I didn't wholly trust the results of this program, especially with some calculations that had not appeared before in other publications.

So I wrote a second program to calculate the diffraction pattern based on an integral appearing in Luneburg. This integral gives an answer coming from a slightly different methodology than that used in the program appearing here. It has the problem partially solved already, and contains the Bessel function explicitly. The two programs agreed on the same problems submitted to them, and are thus self-bolstering, propping each other up where each would not stand alone. I didn't submit this program for publication here because it contains a Bessel function procedure that is copyrighted by someone else. Besides, it doesn't contain all the bells and whistles that my original program does.

Results: Conventional Results

When we submit well-understood pupil functions to the program, we should get well-understood results. I have done so, and the results are shown in the figures labeled Half-Aperture, Narrow-Ring Aperture, Strong Gaussian Aperture, and Obstructed Aperture. We see the same sort of behavior that has already been discussed in the article in TM#24 by Stephen Edberg, although his results do not precisely reproduce mine because his calculations were done in one dimension.

With the Half-Aperture we see a perfect reproduction of the full aperture pattern, only twice as large. The Narrow Ring results in high resolution at the expense of higher rings (thus lower image contrast), just the opposite of the effect we want to achieve. The Strong Gaussian aperture results in near-total elimination of the diffraction rings, limited by the fact that we must truncate the Gaussian somewhere. In the Obstructed Aperture we see a milder form of the high-resolution and higher diffraction rings seen in the narrow annulus aperture. In each of these patterns, the dotted line that gives the results obtained for an unobstructed circular aperture as calculated with a high density of points.

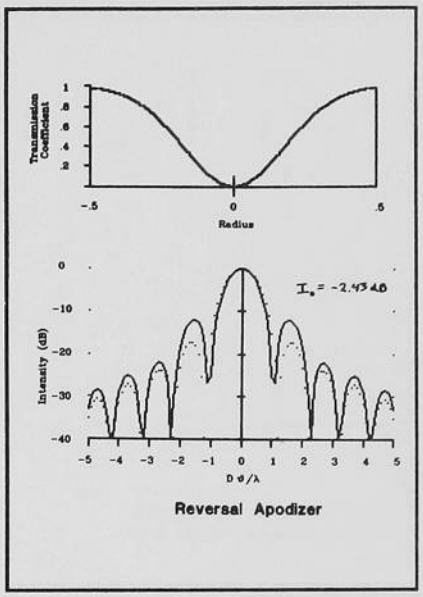
I have also added an entry called Mild Gaussian to illustrate the milder form of apodization available by truncating the Gaussian while it still has a significant value. Many of the patterns appearing in the references look more or less like this, although not all of precisely Gaussian functional form. You can see that the rings are not completely suppressed but are much reduced, and the central disk remains small. In Obstructed Mild Gaussian, however, we see the poisonous effect of the central obstruction on apodization. This pattern is nevertheless an improvement on the straight obstructed aperture pattern.

Another property of apodizers is in the inadvertent improvement of edge difficulties with less-than-perfect optical systems. I have simulated a turned edge, almost a low outer zone, by refocusing some spherical aberration in the figure called Turned Edge. We see that the apodizer still does a fairly good job of reducing rings. Don't expect an apodizer to save you from inferior optics, however. There are many optical problems apodizing won't help.

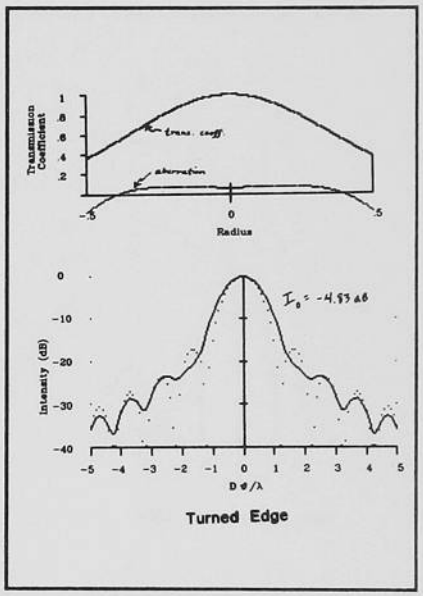
A good example of the mythmaking in this topic is given by the figure labeled Reversal Apodizer. I don't know where I first saw it, but several amateurs have suggested that the same apodizing is possible if you start your transmission equal to zero at the center and gradually increase it toward the edge. This method, were there anything to it, would have the advantage of hiding the secondary. As you can see, it results in a poor image.

I also present the results of a Gaussian starting at a certain radius, which I call Gaussian At Edge. This pattern appeared as Fig. 6 in Edberg's article. I don't know what he did in this one, but in no form does it result in the pattern he calculated. (Note added in proof: In a recent letter, Edberg has indicated that he drew Fig. 6a incorrectly, and that it does not represent the aperture function he actually computed. The transmission of the function he used had only a short stretch of full transmission, rather than the long stretch erroneously shown in the figure.) My calculation, based on the figure in his paper, shows the expected behavior of one of Edberg's apodizer; it is shown in the figure marked Edberg's Screen. Unfortunately, the screens he actually made seem to have been mostly of this type. It is not surprising that screens of this type, especially on a system with a 40%-obstructed aperture, show little or no effect.

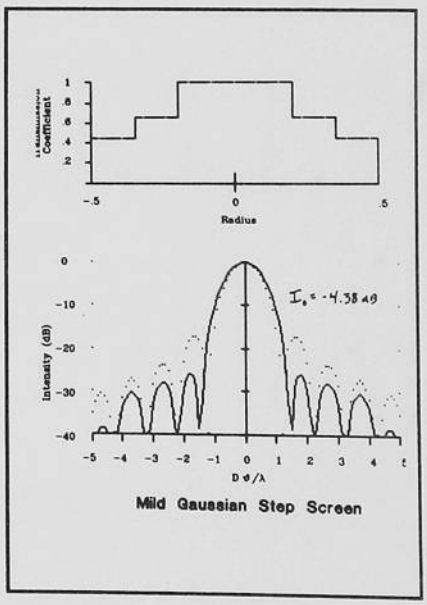
These figures demonstrate the capability of this program and serve to educate the reader in various goals and procedures in apodization. Now we will get down to our real job of calculating screens that the reader is likely to make and use.



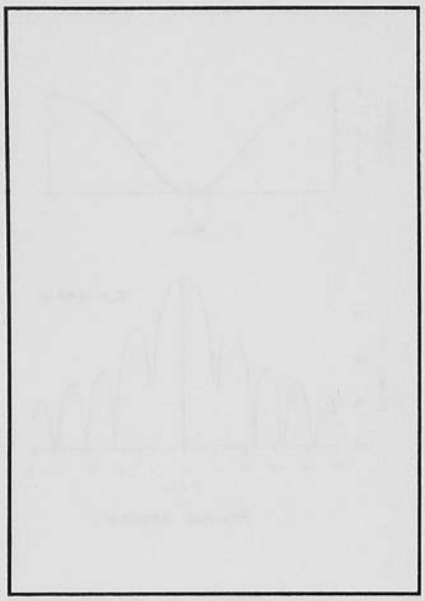
Reversal Apodizer



Turned Edge



Mild Gaussian Step Screen



Step-Screen Results

Our default screen shall be standard 1/14x1/18th-inch, 0.012-inch-strand window screen. In a method that is be made clear later, I found that this screen has a one-thickness transmission coefficient of 0.66. Therefore, it has a two-thickness coefficient of 0.44 and a three-thickness coefficient of 0.29. This is as many thicknesses as I will use. Because of the three-thickness value of .29, the temptation is to try to emulate the mild Gaussian screen, both for higher transmission and to acknowledge the fact that any screen represents at best an approximation of a Gaussian and therefore too slavish an imitation is a waste of time. This response function is given in the figure labeled Mild-Gaussian Step Screen.

Perhaps a mention of why a window screen type of aperture is acceptable and why we can approximate it as a constant transmission value would be helpful. A full description of a diffraction grating (which is what window screen acts like) contains a term giving the diffraction from a single hole and a term giving the interference effect between all the holes. These terms are multiplied together. The first term varies slowly, whereas the second term gives the interference between adjacent minor apertures (i.e., the holes in the screen) and has a resolution that is representative of the entire aperture. If there are enough minor apertures in the grating, interference maxima are cleanly resolved and the zeroth order peak acts just as if it were caused by an aperture comprised of constant lower transmission.

Edberg, in a letter published in TM#26, invokes the uncertainty principle and says something confusing about the inapplicability of window screen. What he says would be correct for only one minor aperture. When there are many minor apertures, and their responses are correlated with each other, then for distances close to the zeroth order image, window screen works fine. The major constraint is that the first order interference maxima must be excluded from the region of interest.

Readers are encouraged to experiment with various ring transmissions and find out what they do. The screen given is by no means the best.

Secondary Diffraction

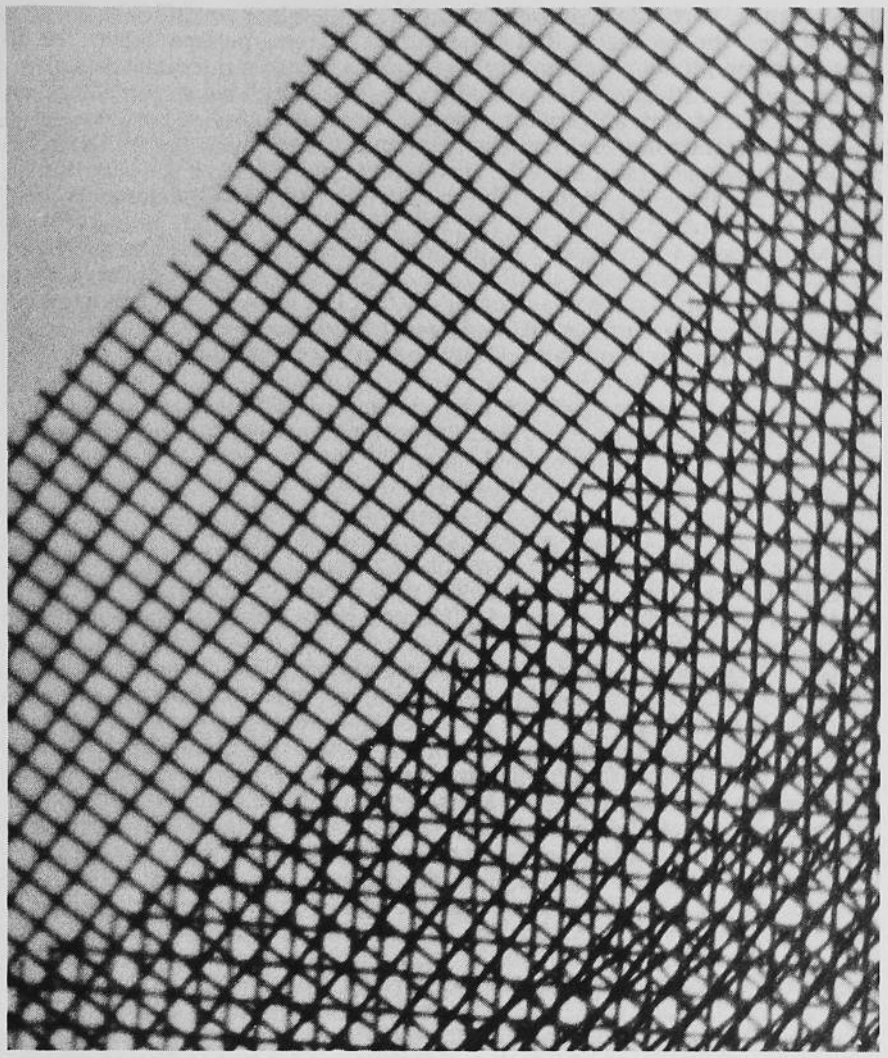
We have been told that secondary diffraction is a major bane of reflectors and there is nothing to be done about it save make the secondary smaller. In my playing around with this program, I discovered that this is not entirely true. If you place a bright ring around the diagonal, the original diffraction behavior is recovered in the first diffraction ring with no loss in resolution of the central disk. There is a beefy second or third diffraction ring appearing beyond that. If you don't try to reproduce the diffraction behavior of the central disk and the first ring too exactly, that extra strong ring can be kept an acceptable 5 dB below the first ring. We can't create intensity in a passive optical system, so the only way we can create the high ring is by shading the remainder. This screen is given in the High Ring Screen figure (HRS for short). Also shown is a HRS for the 30% obstruction common in Schmidt-Cassegrainians.

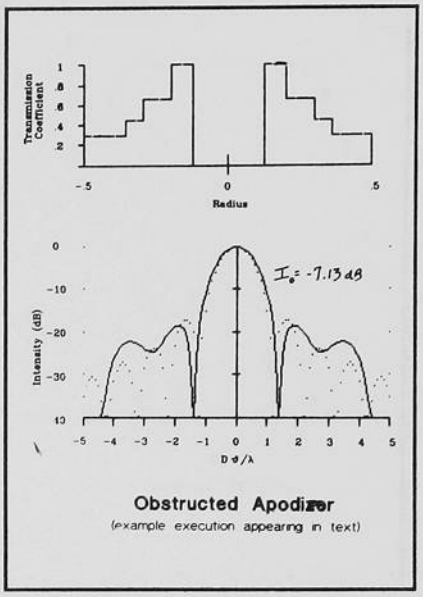
It may seem that we are pulling a fast one on the universe by making this screen, but we have to pay a dear price in two ways. First the image is not as bright. Second, the OTF (not shown) reveals little improvement in the optical system's ability to preserve contrast between incoherent sources. Undeterred, I actually made one of these screens and the good images it produced even with these disadvantages were encouraging. These filters should be a useful tool, along with conventional apodizers, in looking at double stars.

Real Apodizers and How to Make Them

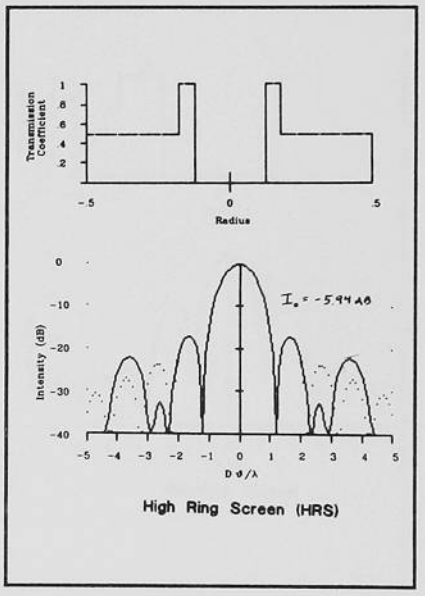
I'm going to assume that 99% of readers who will make an apodizer are going to make one out of window screen. Making one on an optical window is much more difficult and requires sophisticated masking in the vacuum chamber. A warning I will give to those tempted to do it anyway: if you use variable density aluminum on an optical window as a transmission reducer, keep in mind that opacity is not all you are varying -- phase is also affected, although how much I have not calculated.

Another thing to be aware of is the difference between transmission coefficient and energy transmission, usually called the transmittivity. For example, a neutral density filter has a transmission of, say, 0.5 (half the energy going in comes out), but the transmission coefficient that you would

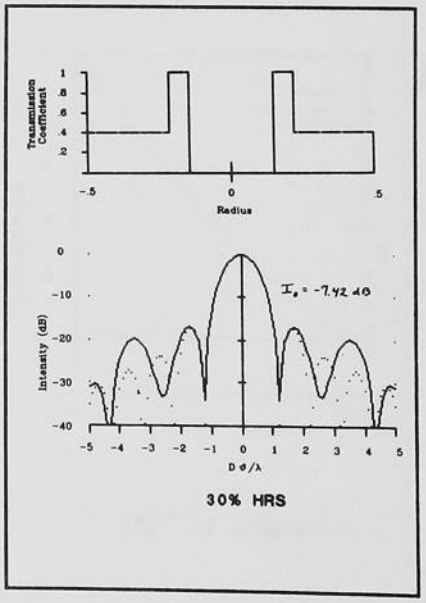




Obstructed Apodizer
(example execution appearing in text)



High Ring Screen (HRS)



30% HRS

give as an input to the program is .7071. The reason for this is that the transmission coefficient multiplies the wave itself, which then must be squared to calculate the energy. I want you to remember this: the pupil function is defined by the transmission coefficient, NOT the transmissivity. If we had inserted a constant factor of 0.5 into the program APODIZE it would have told us (Io = -6 dB) that the energy had been reduced by a factor of 4, leaving us to scratch our heads about where the extra energy went.

The transmission coefficient, and therefore the pupil function, can be negative or imaginary, things forbidden to the energy world. The only constraint on it is that its absolute value not exceed one. The program APODIZE presently will not handle imaginary transmission coefficients. It handles negative ones fine. I have already said this, but it bears repeating.

So, how do we calculate the correct transmission coefficient of a window screen? Simple; we calculate its area. You remember those little Huygens wavelet sources that I mentioned before? The screen acts as a filter for those, if one of them is behind the wire, it is turned completely off. If one of them is in the clear, it is completely on. Actually, it's more complicated than this because of the distortion of the field at the edges of the wires, which further depends on whether the wires are made of metal or a non-conductor. But we may neglect these effects if the wires of the window screen are many wavelengths apart -- and they are. This is called the Kirchhoff approximation.

The fractional clear area is easy to determine. The only thing you have to be careful of is not to double count the strands. Think of each cell of the window screen ascomprised of an L-shape of wire, coupled with a tiny clear aperture. Notice that a complete screen can be made by arranging these L-shapes. Therefore, you should include only one side and one edge per cell to properly calculate the clear vs. obstructed area. Measuring the thickness of

the strands, particularly if they are made of fiberglass, is difficult. (Don't throw away the packaging that came with the screen, pehaps it gives the diameter there.) If it's not given, trying to gauge it with a micrometer is almost useless. Either you'll overmeasure a metal screen because it's bent, or you'll undermeasure a fiberglass screen because it's pinched between the anvils of the micrometer. The best way I found to estimate the width was to separate a single strand from the screen and hold it next to the jaws of a caliper, modifying the width of the caliper until it looked the same as the width of the strand.

My screen (14-per-inch by 18-per-inch, 0.012-inch strand diameter) had a calculated transmission coefficient of .652. I wanted to check this so I stacked up many layers of screening material in front of my camera until it metered an even number off/stops down. The measured value worked out to 0.66, bearing in mind that I really couldn't separate diffracted light from zeroth order light.

Once you have the one-layer transmission coefficient, multiply it by itself to get the two-layer TC, and multiply it again to get the three-layer TC. For example, using my measured value:

one layer = 0.66 = 0.66

two layer = 0.66 x 0.66 = 0.44

three layer = 0.66 x 0.66 x 0.66 = 0.29

After you have cranked these numbers through APODIZE along with some radii and think you have cooked up a screen having a good tradeoff between resolution and lessened diffraction rings, you must make the actual screen.

On a large piece of paper, draw with a compass every diameter of interest: the outside diameter of your mounting ring, the inside diameters of the various layers of flyscreen, and perhaps the diameter of your mirror. (If you have one, use a compass that will draw lines with black ink. It's hard to see a pencil line through window screen.) This is your master template. Set it aside. Make several other templates with the outside diameter of the layer of screen (which is usually the same as the outside of the mounting ring) and the inside diameter set at the radius it's meant to extend to.

Let's work through an example to help you. Say you have a 10-inch mirror that sits in a 12-inch OD tube. You are going to fit a mounting ring of styrofoam that extends further one inch, making the OD 14 inches. You have calculated an apodizer with inner radii of, say, 0.25, 0.35, and 0.42 times the diameter. These radii correspond to 2.5 inches, 3.5 inches, and 4.2 inches. You first make a master template with all radii drawn in. Then you make templates with radii for the individual screens -- 7 inches and 2.5 inches, 7 inches and 3.5 inches, 7 inches and 4.2 inches. You use these individual templates to cut out your screens. Staple them behind a rough square of window screen, and be sure to staple them inside the outer radius -- you don't want them falling off after cutting the outer circle. After you've finished cutting them, carefully remove the staples and the now-used template. Since I made apodizers with fiberglass screen, cutting it out required no more than a pair of scissors. Tools for cutting wire screen include chisels, side cutters, or tin snips, but with such a convenient material as fiberglass around, I can't imagine anyone wanting to do it the hard way.

Once you have all of the layers cut out, arrange them on the master template. Use angles of 0, 60, and 120 degrees (or 0, 30, and 60) for a three-layer screen. Use 0 and 45 degrees for a two-layer screen. Avoid any situation that results in any one screen oriented near 0 or 90 degrees to any other screen. You will then get Moire patterns that possibly will have unplanned-for diffraction structure of their own. Once you are satisfied with the positioning of the layers, go around and staple them together at locations well out of the optical path. Remove the master template but don't remove the staples -- you still need them to hold the whole sandwich together. Attach them to the mounting ring with thumbtacks or staples.

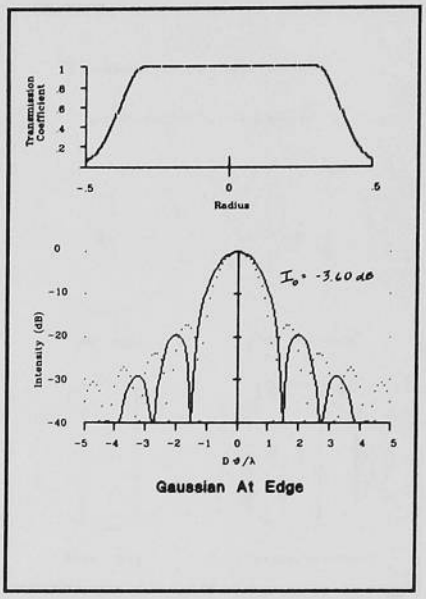
Incidently, for the mounting ring I advise that you use blue, small-cell styrofoam. It's less messy than the white, big celled, stuff which I used. I also advise, unless you have a lot of room in your tractor-trailer, to only make one mounting ring and keep the apodizers in a big folder. Attach them to the mounting ring with thumb tacks when you need them. With small telescopes there is also the option of making apodizers that fit the inside of the tube, and merely laying them carefully against the spider or objective. With bigger telescopes, fiberglass screens tend to flop through the spider.

Screen Sizes and The First Interference Maximum

I happened to mention offhand that we do not have full latitude as to the cell size of our screen. If we use a too-big cell size, we will introduce first order spectra on top of our image of interest. (The location of the first order spectrum is at the angle where adjacent cells seem tilted one wavelength out of phase with each other.) The following table summarizes the angular dispacement of the yellow-green first-order spectrum. The table is approximately linear and can be extrapolated off either end.

radius of first order image at 550 nm	**cell size**
18 arcseconds	1/4-inch onion sack
30 arcseconds	3.78 mm
40 arcseconds	2.83 mm
50 arcseconds	2.26 mm
63 arcseconds	1/14th-inch fly screen

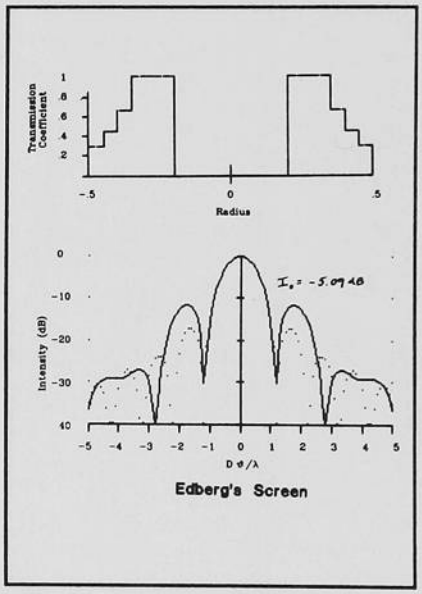
Since Jupiter sometimes gets as much as 50 arcseconds across, this matter isn't just of academic interest. The lesson is clear -- don't use 1/4-inch hardware cloth to make apodizers. Window screen is about as big as we dare go.



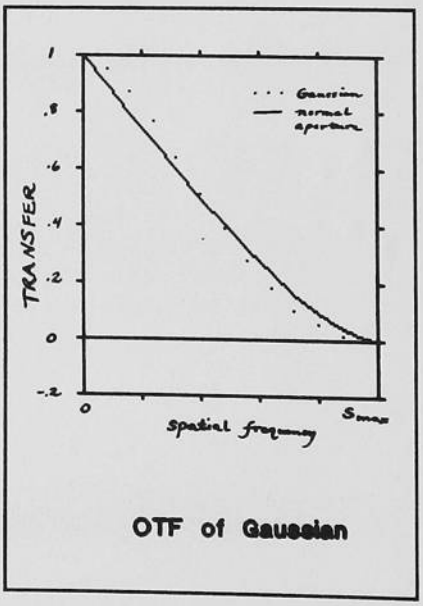
Observational Results

Since the purpose of this article is to enable the readers to calculate and make their own screen and judge the results for themselves, I didn't do much investigation about the performance of these screens. I did look through them, though, and feel qualified to talk about what I saw, especially since I don't have an emotional investment one way or the other.

I made three screens, one mild Gaussian-following step screen, a High Ring screen calculated for a 25% obstruction, and a Null Screen (one having uniform transparency all the way across). The instrument they were tested on was an 8" f/6 Newtonian with a mirror made by me with a good edge, no zones, and a figure better than the error-reading capability of the Couder-screen Foucault test (it calculated out at 1/28th wave on the wavefront, but that's nonsense). It has an E&W 1/20th-wave quartz diagonal. It was well-aligned. The mirror has a small but acceptable amount of roughness, and is supported in a nine-point cell. I use Brandon eyepieces in my regular observing and used them to conduct this test. This qualifies as a fanatic's telescope, as discussed in the introduction. It is the flagship of my fleet.



All three filters, including the null filter, seemed to improve the images of planets. This indicates that much of their function is, as Edberg says, related to darkening the image. On Saturn, the image was rendered bad by poor seeing about 80% of the time. The filters dropped that to 20%. On Mars the effect was even more profound, with those numbers changing to 95% and 5%. I looked for a simpler situation to view; Epsilon Lyrae, nearly overhead, was almost ideal. With a full aperture, I really could not see any rings. Putting on the apodizer, I saw rings, but they were stronger than I had expected. I tried refocusing and that improved the image a lot. That's another characteristic of apodization: the effect is destroyed by anything, including slight focus error. My High Ring screen produced a beautiful single ring around the stars, which were separated by large dark gaps, very similar to the what I saw with the null filter. Again, I saw nothing special about the filters other than their function to reduce the intensity of the image.



Are They "Seeing" Filters?

The question, then, is whether or not these screens act as selective "seeing" filters while retaining much of the telescope's resolution. We can't explain the improvement in image quality from the diffraction behavior. If a wavefront is roughed up by 1/20th wave RMS, and you cut the transmission down to a fraction of its former value, it's still 1/20th wave RMS. In fact, I tried a Gaussian pupil function in my fractal roughness program, and found pretty much what I expected: if roughness is small, apodization works, but if roughness is large, apodization doesn't do a thing. Of course, this is assuming that the effects of turbulence are similar to the effect of

mirror roughness, but I believe that this is a fairly safe assumption.

A simple effect that could explain this behavior is caused by bad seeing itself. It can't be a large-amplitude effect, or the image would be shattered. A simple neutral density filter reduces the intensity of the outer rings to below a certain threshold, below which they are not as noticeable.

This explanation doesn't require that we have a true apodization filter. If we go through the difficult calculation of an apodization filter to cure bad seeing if all we demand is lower brightness, we are wasting our time. A simple filter that reduces the intensity beyond about half of the radius is all that is required.

The OTF of a mild Gaussian pupil aperture can possibly also show us something. We speculate that bad seeing has a more severe effect on high spatial frequencies in the image. The Gaussian filter shifts some of the contrast down to lower frequencies where it can be used (crossover is at half of Smax). Contrast is lowered at high spatial frequencies, but it's raised at low spatial frequencies.

If we accept this explanation, an apodizer doesn't actually doesn't filter out bad seeing, but instead puts the best capabilities of the optical system where we can use them. We have modified the OTF so that the low spatial frequencies that have a chance of penetrating bad seeing are shown at higher contrast.

At one point, I pointed my telescope at a bright star with one of these filters on, and racked the image out of focus. In the dim outer parts of the image, I saw light dancing about wildly. In the full-brightness center of the image, the image was pretty steady. Other times both parts of the image were unsteady. I really don't know if these filters improve seeing directly, but whether they cure seeing difficulties by dimming irradiation, or shifting contrast, or some ill-understood eye-brain interaction, they seem to have an effect on seeing.

Conclusions

My personal opinion is that people have used apodization filters for astronomy primarily as a filter designed to partially cure seeing problems. Their use as a true apodizer has been minimal, for only on exceptional nights with a near-perfect instrument can you see the image differences related to true apodizing.

On the other hand, these screens is so cheap that it is worth making one to wait for that exceptional night. In the meantime, you can use it to cut out some of the difficulty associated with bad seeing.

Perhaps I shouldn't mention my one experience with perfect seeing since I've made these filters. I am ashamed to admit that I preferred the brightness of the unmodified aperture to any improvement that I derived using these filters.

My advice concerning testing the filters is to try to stay dispassionate. Among your filters you should include a couple of filters with varying density that don't modify the relative pupil function but instead have screening clear across, my so-called Null Filter. Test them with some unknowing viewers to see if they can really tell the difference between them and a true apodizer. The advantage of these filters over straight neutral-density filter used in the eyepiece is that the Null Filter have first-order interference spectra similar to apodizers, so people can't give you the answer they think you want to hear. Also, less glass between you and the image allows for fewer sources of aberration creeping in -- I have a couple of neutral density eyepiece filters that always deliver inferior images.

You should also have a mild stop-down mask (one that changes an 8-inch telescope to a 6-inch, for example) to test for effects that have nothing to do with the filter, such as improved ability of the eyepiece at higher focal ratio or the covering of a bad zone at the edge of the mirror. I, happily, see visibly lowered image quality when I stop down my telescope. I probably also see the effects of a larger relative diagonal and the lower resolution associated with smaller mirror size, but it indicates that my telescope is operating near the diffraction limit.

Another thing you should have, as much for the entertainment value as for anything else, is a large obstruction that fits over the end of your spider. I saved the circle I cut from my 6-inch stop-down mask. It excludes all light except for a one-inch-wide annulus. The image from this thing cured me of being tolerant of too-large a diagonal. The diffraction structure is a lot smaller, true, but those rings are full of light.

Use your filters and do not get emotionally involved with the success or lack of it of any filter. Be sure to get critical focus with any change of filter. Perhaps, like me, you'll be pleased that you have added a tool to your bag of tricks, but you'll still be reluctant to give up the unmodified pure aperture. It is, after all, hard to beat.

Apodization Bibliography

This is by no means a complete reference list. My search picked up a lot of uses for apodization. One of the most important was in surface acoustic wave (SAW) filters. It seems as if wherever there is a wave traveling along that is likely to be imaged, there is someone willing to apodize it.

"The Amateur Astronomer" conducted by Albert G. Ingalls, Scientific American, three issues:
May 1951 -- letter by Webb.
August 1951 -- refutation of Webb's suggestion, letters from Sinton and others, suggestion of full aperture modification.
June 1954 -- letter from Arthur Leonard describing practical methods for doing apodization.

R.K. Luneberg (note: name Luneburg was misspelled in first edition) Mathematical Theory of Optics, Brown Univ. Press 1944. -- very difficult, abstract.

H. Osterberg and J.E. Wilkins, Jr. "The Resolving Power of a Coated Objective" Journal of the Optical Society of America (JOSA) vol 39, no 7, pg 553 July 1949 -- an early pupil function for the circular aperture, more concerned with resolution.

Pierre Jacquinot "Apodization" in Appendix E of John Strong's Concepts of Classical Optics, Freeman and Co., 1958.

Richard Barakat "Solution of the Luneberg Apodization Problems" JOSA, vol 52, no 3, pg 264, March 1962 -- pupil functions appear as expansions in polynomials.

J. Ernest Wilkins, Jr. "Luneberg Apodization Problems" JOSA, vol 53, no 1, April 1963 -- discussion of Barakat, new problems stated, pupil function expanded in terms of Bessel functions.

P. Jacquinot and B. Roizen-Dossier, "Apodisation" (possibly a British spelling?) Progress in Optics, ed by E. Wolf, vol III, pg 29, North Holland Publishing 1964 -- good review article.

Slepian, David "Analytic Solution of Two Apodization Problems" JOSA vol 55, no 9, pg 1110, Sept. 1965 -- worked for slit or circular aperture.

Papoulis, Athanasios "Apodization for Optimum Imaging of Smooth Objects" JOSA vol 62, no 12, pg 1423, December 1972

M. Mino and Y. Okano "Improvement in the OTF of a Defocused Optical System Through the Use of Shaded Apertures" Applied Optics, vol 10, no 10, pg 2219, October 1971 -- very understandable description of the effect of an apodizer in the presence of an aberration, includes interesting photographs.

John N. Kibe and J. Ernest Wilkins, Jr. "Apodization for maximum central irradiance and specified large Rayleigh limit of resolution. II" JOSA-A, vol 1, no 4, pg 337, April 1984.

H. Tschunko "Imaging performance of annular apertures. 4: Apodization and point spread functions" and "5: Total and partial energy integral functions" Applied Optics, vol 22, no 1, pgs. 133 and 137, 1 January 1983.

Dick Suiter
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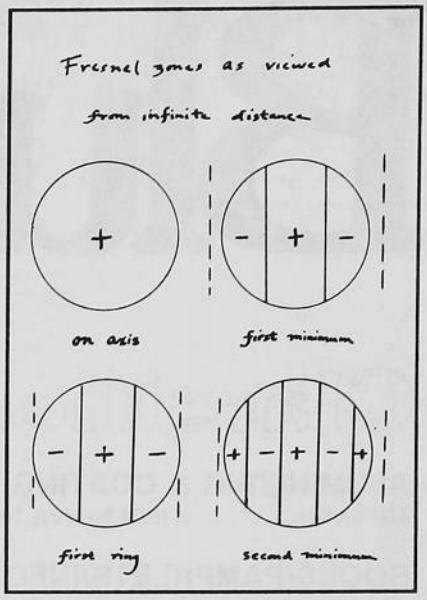

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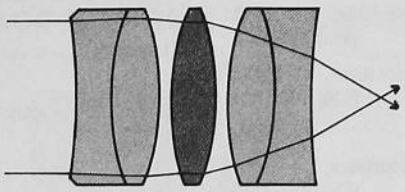

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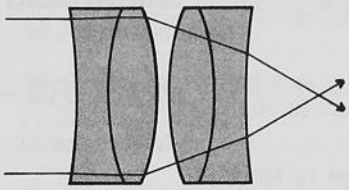

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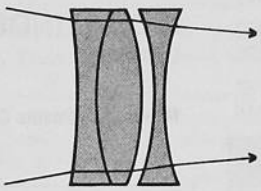

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9.7mm	52°	1¼"	Yes
12.4mm	52°	1¼"	Yes
15mm	52°	1¼"	Yes
20mm	52°	1¼"	Yes
26mm	52°	1¼"	Yes
32mm	52°	1¼"	Yes
40mm	44°	1¼"	No
56mm	52°	2"	No
Super Wide Angles (6-elements)			
13.8mm	67°	1¼"	Yes
18mm	67°	1¼"	Yes
24.5mm	67°	1¼"	Yes
32mm	67°	2"	No
40mm	67°	2"	No
Ultra Wide Angles (8-elements)			
4.7mm	84°	1¼"	Yes
6.7mm	84°	1¼"	Yes
8.8mm	84°	1¼" & 2"	Yes
14mm	84°	1¼" & 2"	No
Barlow Lenses (3-elements, air-spaced)			
#140 2X Telenegative Amplifier		1¼"	Yes
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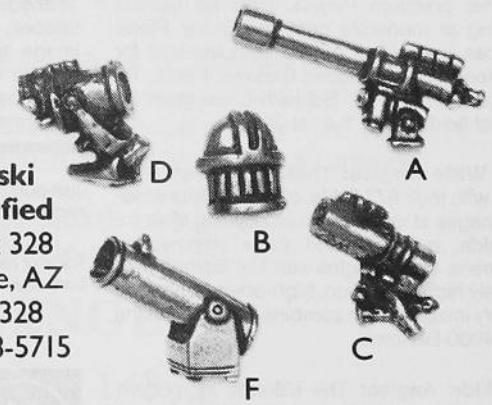

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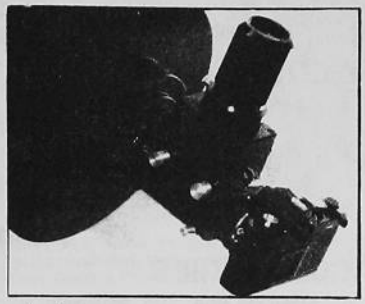

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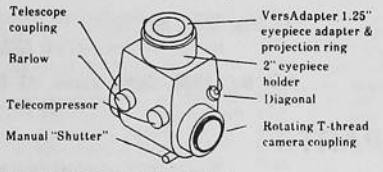

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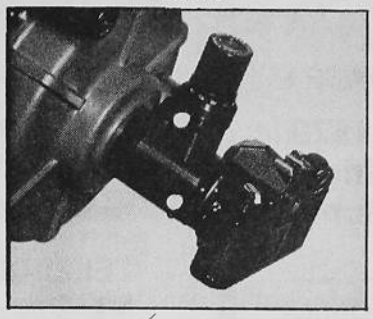

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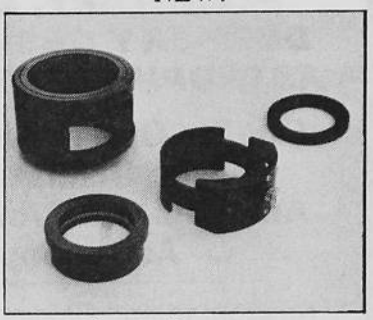

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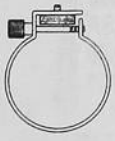

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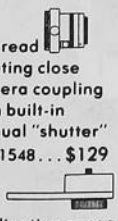
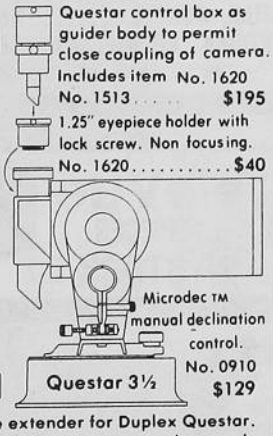
Compact fast attachment piggyback mount
No. 0915 .... $149

1.25" eyepiece holder with lock screw. Non focusing.
No. 1620 ..... $40

P-thread rotating close camera coupling with built-in manual "shutter"
No. 1548 ... $129





No. 0910 $129

Declination range extender for Duplex Questar. Balances telescope with camera and extends photographic declination coverage to a wide plus 71 degrees to minus 49 degrees!
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0.6x Telecompressor (not shown) No. 1562.. $79.95

Also see No. 0131, 1411, 1533, 1571-1583, 1691

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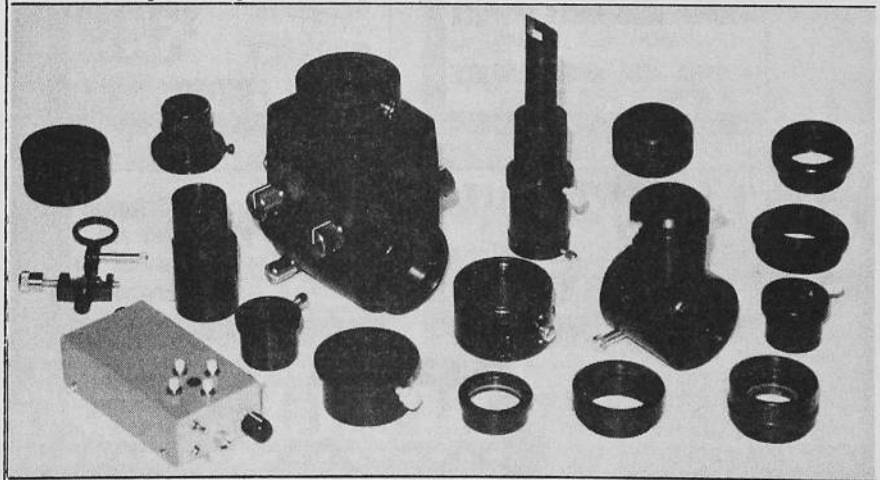

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All prices in U.S. dollars and subject to change without notice. AZ res. add 5% tax. Approx. shipping charges for cont. U.S.: VersAgonal: $10. DiaGuider: $8. Most other items: $3.50. Forgein orders sent by air with shipping collect. Send S.A.S.E. for free catalog.

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ASTROPHOTO OF THE MONTH

Crab Nebula M-1 in Taurus. The Crab Nebula is seen best visually with a LUMICON DEEP-SKY Filter. Photo by David Healy using a LUMICON Giant EASY-GUIDER and LUMICON hypered 2415 film. 33 min. exposure, Celestron-14 at f/6.

20mm NAGLER

New 2" eyepiece with 82° field $295

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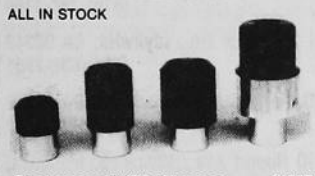

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32mm Plossl, widest true field in 1¼"	$110
55mm 2" Plossl, widest possible field	$190
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19mm Wide-Field, 1¼" eyepiece, 85°	$145
24mm Wide-Field, "superb," 65°	$160
32mm Wide-Field, 2" eyepiece, 65°	$230
40mm Wide-Field, "awesome," 65°	$295
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7mm Nagler, 1¼" eyepiece, 82° field	$185
9mm Nagler, 82° field, "the best"	$225
11mm Nagler, 82° field, 1¼" or 2"	$240
13mm Nagler, 82° field, 1¼" or 2"	$250
20mm Nagler, 82° field, 2" eyepiece	$295

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Upgrade to 48mm filters! All are multicoated

UV, Green, Yellow, Orange, Red	$18 each
48mm H-Alpha Pass (640nm cut-off)	$35
48mm Minus Violet (420nm cut-off)	$29
48mm High perform blue, 90% trans	$35
Central Star Filter (blue tri-color) 340-470nm bandpass	$35
UV-370 U-Band, 320-420nm bandpass	$35
48mm Polarizer (2 make variable density)	$18
Set 9 ea. 48mm filters ($259 list)	$195
2"/1¼" adapter threaded for 48mm filters	$20

H-ALPHA PASS FILTER

Yields spectacular contrast gains in B&W photography with telephoto lenses. Yields pinpoint star images. Superb with hypered 2415. For color, use the Minus Violet (MV) Filter.

Specify Lens Size	H-Alpha	(MV)
46, 48, 49mm	$35.00	$29.00
52, 55, 58, 62mm	$45.00	$35.00
67, 72, 77mm	$52.00	$45.00
82mm	$55.00	

Hypered 2415 film, 36 exp . . . **$10.95** . . . **3/$29**

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LUMICON 1.3" & 3.1" enhanced silver diagonal mirrors & 2" star diagonal.
The new LUMICON diagonal mirrors have a special enhanced silver coating with a protective overcoating for long life. Visible reflectivity is 98-99% compared to 86-89% for standard aluminum coated mirrors. The extra 10-12% transmission is like adding an inch of aperture! The substrate is fine annealed Pyrex flat to 1/8 wave.

1.32"	**$29.95**	1.52"	**$34.50**	1.83"	**$39.50**
2.14"	**$49.50**	2.60"	**$65.00**	3.10"	**$89.50**
4.25"	**$149.50**				

ENHANCED SILVER STAR DIAGONAL

90° star diagonals with above enhanced silver mirrors in a CNC machined black anodized aluminum body. Performance far exceeds prism diagonals.

1¼" (1.32" mirror)	**$89.50**
2" (1.83" mirror)(see photo above)	**$145.00**

OXYGEN-III FILTER

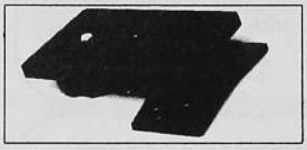
Helix Nebula, NGC 7293 in Aquarius. Bright and easy with Lumicon Oxygen-III Filter.

The ultimate in filter performance! The Lumicon Oxygen-III Filter has a contrast twice as high as the high performance Lumicon UHC Filter™. Use the Oxygen-III Filter for observing the very faintest planetary and diffuse emission nebulae. Also gives incredible views of bright nebulae (like M-27, M-17, etc.) from urban locations. Bandpass is 11nm, transmission is 90% for both O-III lines at 496nm and 501nm.

Filter Type	1¼"	48mm
Lumicon Oxygen-III	**$99.50**	**$199.50**
Lumicon UHC	**$99.50**	**$199.50**
Lumicon Deep-Sky	**$79.50**	**$119.50**
Set UHC and Oxygen-III	**$190.00**	**$380.00**

NOTE: The Oxygen-III Filter is not a substitute, but a compliment to the UHC Filter. **1 year guarantee:** You must see nebulae with the OIII filter that are **invisible** without a filter.

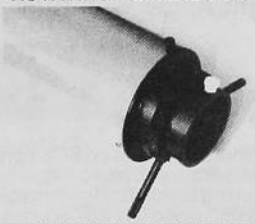
NEW ADJUSTABLE PIGGYBACK MOUNT



LUMICON has just designed a new adjustable piggyback mount ideal for all telescopes of 8-14" aperture. It has **both** vertical and sideways adjustment to allow optical alignment. It was designed to allow mounting of the LUMICON SUPER-FINDER on C-8, C-14, etc., but is ideal for any telephoto lenses or small telescopes.

Deluxe Piggyback Mount (State Telescope Type)	**$45.00**
LUMICON 12x80mm SUPER-FINDER	**$170**

LOW PROFILE NON-ROTATING HELICAL FOCUSER



LUMICON® DELUXE NON-ROTATING HELICAL FOCUSER on a SUPER-FINDER

LUMICON has just designed a deluxe smooth helical focuser with non-rotating 2" I.D. eyepiece holder. It has a vertical travel of 1¼" and a very low profile, only 1¼" high. It is CNC machined, black anodized, and a perfect match to a LUMICON Newtonian EASY-GUIDER.

Select your desired base-plate shape! Flat, 7" OD, 9½" OD, 12½" OD, 16" OD, 20" OD, SUPER-FINDER base plate.

LUMICON Deluxe Helical Focuser	**$79.50**
3 handles (see photo)	**$12.95**
Helical focuser with 3 handles	**$92.45**
2"/1¼" adapter w/48mm filter threads	**$20.00**
2" LUMICON EASY-GUIDER	**$139.50**

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1½"	2/$2	9½", 10.4"*	$12
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*Fits Odyssey

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U.S. Patent 4,473,636

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U.S. Patent # 4,448,500

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Full aperature. Installs in secs. Specify 2" or 1¼".

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3X Relay Diagonal (see photo)	**$79.50**
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For C-8, Meade 2080, Dynamax-8. Includes 50mm achromatic lens for f/5.8 operation-3X shorter exposures! **Superb rich field viewing, too!**

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For Celestron-11, C-14, and the 10" Meade 2120. Includes 80mm clear aperture achromatic lens for edge-to-edge illumination & pin-point star images. F-ratio adjustable f/4-f/11. **Also yields unmatched Rich-Field viewing.**

GIANT EASY-GUIDER	**$395.00**
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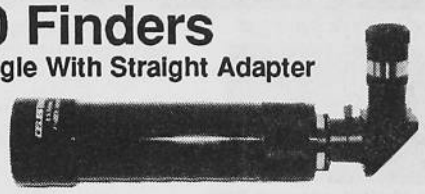
Right Angle With Straight Adapter



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*Limited Quantities

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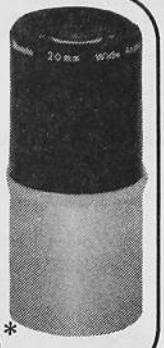

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"Used with my 12" f/7, the Plössls deliver crisp images of the planets. I have the distinct impression that the eyepiece adds no optical errors to the image I'm viewing, and that I am seeing everything the mirror can deliver. This is an impression I've never had with any other eyepiece. Tele Vue Plössls are the sharpest I've ever used." — From review in August '81 "Astronomy"

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32mm
26mm
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17mm
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10.4mm
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BARLOW
2.5x
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WIDE FIELDS
40mm
32mm
24mm
19mm
15mm

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13mm
11mm
9mm
7mm
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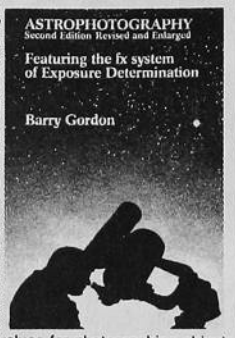

Dennis di Cicco wrote in the December 1983 *Sky and Telescope* "Perhaps the most innovative section of the book is Gordon's approach to determining the correct exposure. He has developed what he calls the "*fx* system," whereby the basic elements of film speed, exposure duration, and f/number are assigned simple numerical values. Each scene, whether a daytime landscape, the Moon's surface, or Jupiter, is given an *fx* value for the appropriate exposure. It is a simple matter to add the appropriate values of different elements to arrive at the correct *fx* for the scene...I was impressed with Gordon's *fx* values for photographing objects like M27 and M57. Working through the simple formula described earlier, I found that some of my best exposures correspond closely to *fx* values recommended in the book... Overall, *Astrophotography* is an excellent book with a lot to offer." Now this 2nd edition has been revised and enlarged with more than 75 photographs (many full page), 32 tables and 7 line drawings. If you are new to astrophotography this book will get you going with good results right from the start.

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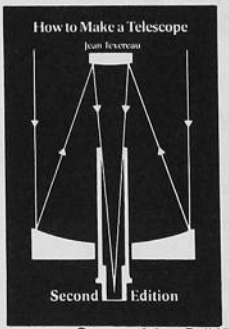

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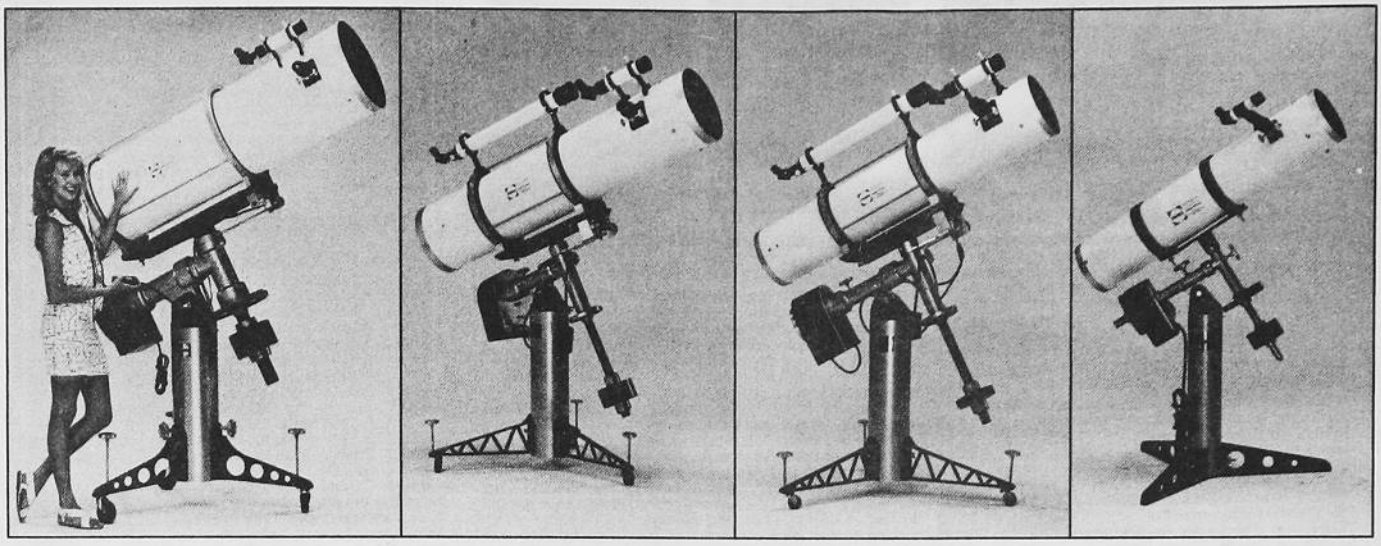

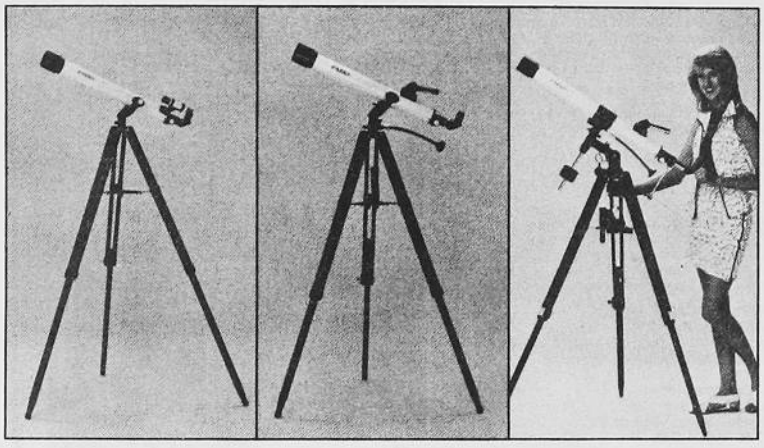

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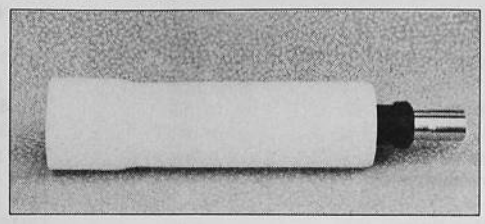

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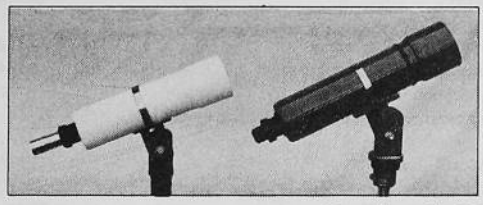

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